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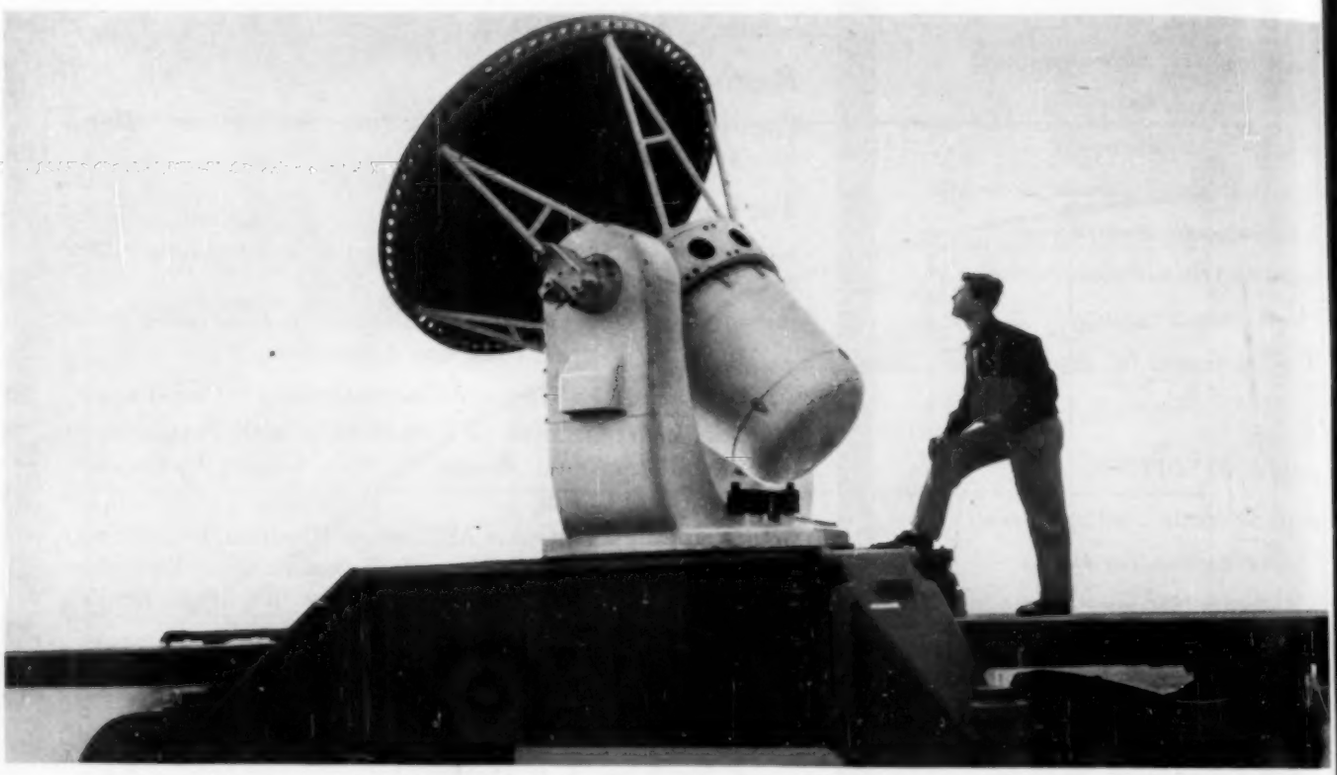
TELEPHONE SCIENCE GUIDES A PUNCH NO ENEMY CAN DODGE



(Upper left) – Nike's missile climbs to destroy an enemy, under guidance of complex electronic controls. A radar is shown at right. Nike (pronounced Ny'kee) is named after the Greek goddess of Victory.

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Editorial

Service

Our Government was founded on service by men of integrity, seeking better things from life. The fathers of our constitution gave freely of their service and sacrificed much materially to attain the form of government from which we have received so much in opportunity for the better things of life and opportunities to give service to our fellow men.

Likewise, all successful societies and organizations, technical or otherwise, should be founded on service of the individual to that society or organization. Only through service can we attain the highest standards and ideals and true enlightened fellowship.

It was service and sacrifice over the past few years by the able officers of your Society that has brought The Electrochemical Society to its high state of technical perfection. These officers, working with determination and unity of purpose, have brought the Society into well-being financially and technically. The JOURNAL of the Society has taken its place among the best in its field. Divisions have been revived, new Divisions added, and standards raised all along the line.

There is still much to do that demands the service, sacrifice, and devotion of all the members in order to maintain the standards we have attained through the service of our past officers.

Your Society has grown until it has taken on the character of big business. Like any business, costs of operation have risen these past years, yet our dues are low and within the reach of all worthy candidates. In order to maintain our position, the Society needs new members. It is the best way to keep the benefits of our Society within reach of all and still maintain our present high quality.

May we ask that in the coming year all Divisions and all Local Sections give service toward gaining new members. I am sure the field is ripe if we but give a little of our time to the task. There are many young technical men and scientists who are eligible to become members of The Electrochemical Society. The Society will benefit by having them, as active members, ready to take part and to give service to The Electrochemical Society that it may maintain its high prestige in the engineering and scientific field.

—MARVIN J. UDY

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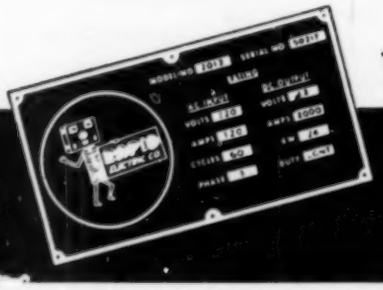

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ELECTROPROCESS PLANTS IN THE TVA POWER SERVICE AREA

Harry A. Curtis[1]

Introduction

The area served by the TVA power system is approximately twice that of the Tennessee River drainage basin. It does not include all of any one state, but covers most of Tennessee and some of the adjacent parts of Virginia, North Carolina, Georgia, Alabama, Mississippi, and Kentucky. The total power service area is approximately eighty thousand square miles.

Most the electroprocess plants in this area were built after 1933 when development of the power potential of the Tennessee River was undertaken by the TVA incident to control of the river. Relatively cheap power has no doubt been a factor, but by no means the only factor, in the rapid industrialization of the region in recent decades. The mild climate, abundant water supply, available man power, natural resources of the region, water transportation, location of expanding markets, and several other factors have also been favorable. Establishment of electroprocess industries has been part and parcel of the general industrial development now in progress.

The number of electroprocess industries locating in the region during the past twenty years is actually small in comparison with the number of other industries established in the region in the same period, i.e., less than a score of the former as against more than two thousand of the latter. In other words, the general industrial growth in the region is of much greater significance than is the establishment of a few relatively large electrothermal or electrolytic process plants. This is not to minimize the importance to the region of the large electroprocess plants, for, aside from the many other benefits they bring, the basic electric load at a high load factor that characterizes such plants makes possible lower electric energy rates for the small domestic users of power from the same power network.

Classification of Electroprocess Industries

The two types of electroprocess industries included in the title above differ from each other primarily in the functions served by the electrical energy consumed. For purposes of the present discussion, electrothermal processes are defined as those in which the electric energy is all converted to heat, and electrolytic processes as those in which at least a considerable part of the electric energy is used as such in the chemical reactions involved. Economically considered, this distinction is not significant since, so far as electrical energy consumption is concerned, the important consideration is the over-all quantity of electrical energy used per unit weight of product or products. Equipment required for a specific application of either process will be different for each application, and if the process be of the electrolytic type a part or all of the energy used must be in the form of direct current as contrasted with an electrothermal process where, for a variety of reasons, alternating current is normally preferred.

In an electrothermal process, the heat derived from the electrical energy consumed is utilized to meet several requirements. In a phosphate smelting furnace, for example, heat distribution in a large furnace (say one drawing 12,500 kw) will be about as follows:

	% of total
Net heat requirements of the chemical reactions	51
Sensible heat in the slag tapped from the furnace	29
Heat losses from the surfaces of the furnace and electrodes	9
Sensible heat in the furnace offgases	5
Sensible heat in the ferrophosphorus tapped from the furnace	1
Heat not accounted for	5
Total	100

Obviously, the typical heat distribution given above will vary with several factors, particularly with the grade of rock phosphate used, and, of course, each electrothermal process will show a different heat distribution.

In processes that are here classified as electrolytic, there is likewise a wide variation in the proportion of electrical energy used to meet the several requirements of the particular processes. For example, in a chlorine-caustic cell, only a small proportion of the electrical energy is used other than in the electrochemical reaction. On the other hand, in the process used for the electrodeposition of aluminum, a considerable proportion of the total energy supplied is used to maintain the pot and pot contents at the necessary temperature. A typical distribution of the electric energy supplied to an aluminum-producing cell would be about as follows:

	%
Heat in aluminum removed	5.9
Heat in waste gases	7.7
Other heat losses	46.4
Energy used in chemical reactions, mostly electrolytic	40.0
Total	100.0

In a survey of the electroprocess industries of a region, such as will be attempted in the present article, it is necessary to make some arbitrary decisions as to what operations are to be listed as electroprocesses. Plants producing elemental phosphorus, calcium carbide, aluminum, chlorine-caustic, and electrolytic manganese are clearly electroprocess plants. Another group may also be classed as electroprocess plants because the high temperatures used are not readily obtained except in electric furnaces. In this group fall plants producing ferrosilicon, ferrochrome, and other ferroalloys. However, in a third group of plants the use of electrothermal operations is convenient and economical, but is not essential. These plants use a great variety of electrically heated ovens, muffles, and crucibles primarily for convenience and ease of temperature control. This group of plants includes those making enamelware stove parts, vacuum bottles, gas heaters, clothes

[1] Tennessee Valley Authority, Knoxville, Tennessee.

Electrochemical Plants

	Year plant established*	Employees 1952*	Million kwhr used in fiscal year ending June 30, 1953†
Aluminum			
Aluminum Company of America	1913	8000	3,148
Reynolds Metals Company	1940	—	940 (smelting)
Chlorine-caustic			
U.S. Government, Wilson Dam, Alabama	1952	—	—
U.S. Industrial Chemicals Company	1942	—	59
Pennsylvania Salt Manufacturing Company	1949	114	Started in fiscal 1950. Now at rate of about 80
Velsicol Corporation	1946	100	34
Hydrogen-Oxygen			
Wilson and Company	1916	125	9.4
Electroplating			
Southern Electroplating Company (two plants)	1945	40	0.7
Manganese			
Electro Manganese Corporation	1939	126	37

Electrothermal Plants

Phosphorus			
TVA at Wilson Dam	1933	—	550
Monsanto Chemical Company	1936	500	895
Victor Chemical Works	1938	475	393
Shea Chemical Corporation	1952	175	Started in fiscal 1953. Now at rate of about 250
Carbide			
U.S. Government at Wilson Dam	1918	—	Plant idle
National Carbide Company	1952	205	Started in fiscal 1953. Now at rate of 500
Ferroalloys			
Tennessee Products and Chemical Corporation (two plants)	1917	690	246
Electro Metallurgical Company	1940	500	464
Pittsburgh Metallurgical Company	1949	264	284
Montana Ferroalloys, Inc.	1952	—	Estimated 92
Foundries			
Ross-Meehan Foundries	1889	450	18
Knoxville Iron Company	1868	500	13
Electrodes			
National Carbon Company	1937	300	141
Miscellaneous (using 2–24 million kwhr annually)			
Aladdin Industries, Nashville	1949	350	
American Lava Corporation, Chattanooga	1902	—	
Cleveland, Tennessee Enamel Company	1928	300	
Crane Company, Chattanooga	1921	1200	
Ferro Corporation, Nashville	1946	120	71
Florence Stove Company, Lewisburg, Tenn.	1869	500	
Gray and Dudley, Nashville	1862	250	
Murray Mfg. Company, Murray, Ky.	—	613	
Polynesian Arts, Inc., Mayfield, Ky.	—	182	
Temco, Inc., Nashville	1921	350	

* Nearly all of these data are from the 1952 edition of the *Directory of Tennessee Industries*. The number of employees shown presumably is for whole plants and does not indicate the number engaged in electroprocess operations only. Also it should be noted that the data for employees refer to the calendar year 1952 whereas the energy consumption is for the fiscal year ending June 30, 1953.

† All figures are for whole plants unless otherwise indicated.

dryers, etc., and those using electrically heated furnaces in melting scrap iron. The group is large and makes many products. In the present survey, some of the larger of these plants will be listed and discussed very briefly, although it is not logical to classify them as electroprocess plants. Some of them use relatively large amounts of electric energy, however.

The accompanying classification of plants in the TVA power service area is admittedly arbitrary and purposely omits the hundreds of plants that use electric energy only for such purposes as lighting, space heating, operation of motors, and other electromechanical devices, and also omits mention of scores of little plants that use electroprocess operations incidentally or on a very small scale.

Relative Importance of Electroprocess Industries in the TVA Power Service Area

It is pertinent to the present review to indicate, if possible, the amount of electric energy consumed by electroprocess industries in the region as compared with the electrical energy used by other consumers. The quantities of energy used by the larger electroprocess plants have been shown in the table above, but it is not possible to give an accurate picture of the

whole situation. In the first place, there is a very large group of small plants in which electrothermal or electrolytic operations are incidental, and the energy thus consumed is a small part of the energy used in the plant as a whole. Data as to energy consumption in each plant of this large group could be assembled, but it would be a difficult and time-consuming task to separate the relatively small fractions of the total energy consumption that was used in electrothermal or electrolytic operations. A still larger distorting factor is the fact that the Atomic Energy Commission plants and a few other defense plants in the region use a very large amount of energy, some of which is undoubtedly applied in operations that would be classed as electrothermal or electrolytic. It is not permissible to discuss these defense plants but only to note in passing that they no doubt add considerably to the electroprocess energy consumption in the region.

The total quantity of electrical energy entering the TVA power net in fiscal 1953[2] was 27,348 million kwhr. This came from the TVA hydroelectric and steam-electric plants, from the Alcoa hydroelectric plants operated as a part of the TVA system, from the federally owned hydroelectric plants on the Cumberland River, and from privately owned companies under power purchase and exchange contracts. This energy was distributed as follows:

	Million kwhr	%
To distributors of TVA power	10,986	40.2
To directly served large industries	6,787	24.8
To Federal agencies	6,967	25.4
TVA interdivisional	619	2.3
Returned to neighboring power systems	654	2.4
System losses	1,335	4.9
Total	27,348	100.0

The total energy consumption by industries was about 18,150 million kwhr, of which 6967 million was by Federal agencies other than the TVA. As pointed out above, it is not known what part of the 6967 million kwhr of energy taken by Federal agencies other than the TVA should be classified as electroprocess. Nor is it known what part of the use by the industries served by TVA power distributors or directly by the TVA should be classified as electrochemical. Obviously, then, no accurate statement can be made as to the total electroprocess energy consumption in the region. However, the partial picture for the industries listed in the table is about as follows:

	Million kwhr annually	%
Aluminum	3750	44.41
Chlorine-caustic	253	3.00
Hydrogen-oxygen Electroplating	10	0.12
Manganese	37	0.44
Phosphorus	2063	24.44
Carbide	1000	11.85
Ferroalloys	1086	12.86
Foundries	31	0.37
Electrodes	141	1.67
Miscellaneous	71	0.84
Approximately	8442	100.00

Aluminum-Producing Plants

There are two aluminum-producing plants in the region, that of the Aluminum Company of America, first established some forty years ago at Alcoa near Maryville, Tennessee, and the relatively recently built plant of the Reynolds Metals Company near Sheffield, Alabama.

Aluminum Company of America, Alcoa, Tennessee

The Aluminum Company of America began construction of its works at Alcoa, Tennessee, near Maryville, in 1913 and first poured aluminum in March 1914. The story of this operation has been one of frequent expansions over the past forty years until today it is a very large installation, the company's largest.

The initial smelting plant included only two "pot rooms" as they were called in those years. Power was purchased from the Tennessee Electric Power Company. The company's plans were, however, to produce its own hydroelectric power and for this purpose power plant sites had been purchased on the Little Tennessee River and its tributaries. Power from the company's Cheoah Dam was produced in 1919, followed by power from the Santeetlah Dam in 1928, the Calderwood Dam in 1930, the Thorpe (Glenville) Dam in 1941, and the Nantahala Dam in 1942. The name plate capacity of the generators installed at these five dams was about 360,000 kva. Some additional capacity was added later and the company has lately built or is now building some relatively small dams. The present capacity of the company's hydroelectric installations is about 415,000 kva.

Up to 1937 expansion of the company's power production facilities kept pace with the expansion of the Alcoa works, but when it then appeared that there would be a great need for aluminum, the company nearly doubled the capacity of the smelting plant, using power from the TVA net. In 1940–41 the world's largest aluminum rolling mill was added. At present the Alcoa works produces ingot, plate, sheet, foil, and pigment.

The smelting installation, which is the electroprocess part of the plant, is the largest aluminum reduction plant owned by the company. The floor space occupied is some 42 acres. The cells in the pot lines are of various sizes, some using Söderberg self-baking electrodes and some using prebaked carbon electrodes. The prebaked electrodes and carbon paste for the Söderberg electrodes are manufactured in the company's local electrode plant. About 0.75 lb of carbon electrode is required per pound of aluminum produced.

Initially, the bauxite ore from which the alumina used at Alcoa was produced was mined in Arkansas and refined in East St. Louis, Illinois. Later on, about 1917, the company opened bauxite mines in British Guiana, and some five years later began shipment of bauxite from this source. Later on, larger mining operations were begun in Dutch Guiana, and the ore was shipped to East St. Louis for refining. In 1937, when the Alcoa smelting plant was greatly expanded, the company built a bauxite-refining plant at Mobile, Alabama, whence most of the oxide for cell feed now comes. The company has, however, continued bauxite production in Arkansas on a relatively small scale and in 1952 built a plant to handle low grade Arkansas bauxite. Cryolite for the cells was originally imported from Greenland, but at present synthetic cryolite is used almost exclusively.

In 1941 the Aluminum Company of America and the TVA signed an agreement under which the company's dams and hydroelectric power installations are now operated as a part of the TVA power system, and the TVA supplies the company's total power requirements. In fiscal 1953 the Alcoa smelting plant produced about 140,600 tons of primary aluminum.

[2] Throughout this article the fiscal year refers to the year ending June 30.

Reynolds Metals Company, Sheffield, Alabama

Construction of the Reynolds Metals Company's Listerhill reduction plant near Sheffield, Alabama, was begun in 1940 and the first aluminum poured in May 1941. The company had long pioneered in the fabrication of aluminum foil and its use in many forms. It had also produced aluminum powder and by 1940 was fabricating aluminum sheet, rod, bar, and structural forms.

Prior to 1941, Alcoa was the only producer of primary aluminum in the United States. The Listerhill plant was the Reynolds concern's first venture in the field of primary aluminum production.

The Reynolds Mining Corporation began the mining of bauxite in Arkansas in 1940, and in 1952 the Reynolds Jamaica Mines, Ltd., began shipment of Jamaican bauxite to the several refining plants now owned by Reynolds. The company also has large holdings of bauxite in Haiti and is now beginning production from these deposits.

The Listerhill plant has been expanded from time to time since 1940, and the company has also leased part of the buildings and grounds of U. S. Nitrate Plant No. 1 several miles from the Listerhill plant. In addition to primary aluminum, the company's plants near Sheffield now manufacture aluminum sheet, rod, bar, building materials, foil, and steel-reinforced aluminum cable.

The capacity of the Listerhill reduction plant is stated to be nominally 50,000 tons of aluminum per year. At 20,000 kwhr per ton of aluminum produced, the energy consumption of the plant at capacity would be about a billion kwhr per year. In fiscal 1953 the energy consumption of the reduction plant was actually 940 million kwhr with an average monthly load factor of 99%.

Chlorine-Caustic Plants

There are four chlorine-caustic plants in the region, namely, the U. S. Government plant near Sheffield, Alabama, built by the Monsanto Chemical Company for the Chemical Corps during the Korean trouble but never operated except in a trial run; Government-owned installations at Huntsville, Alabama, consisting of two chlorine-caustic plants, a part of the Redstone Arsenal, built during World War II and at present leased and operated by the U. S. Industrial Chemicals Company; the Pennsylvania Salt Manufacturing Company plant at Calvert City, Kentucky; and the Velsicol Corporation plant at Memphis, Tennessee.

U. S. Government Plant, Muscle Shoals, Alabama

This plant was built by the Monsanto Chemical Company for the U. S. Army. It was the first large plant in the United States in which DeNora cells were installed.

The DeNora cell is in the form of a long and narrow steel trough lined with a suitable material. Anodes are cylinders of graphite that pass through seal rings in the hard rubber cover of the trough. A thin stream of mercury flows along the floor of the cell and dissolves the sodium as it is formed. The mercury-sodium amalgam leaving the cells is pumped to the top of a steel tower packed with lump graphite. As the amalgam flows down over the packing it is brought into contact with water. The resultant caustic solution and mercury are withdrawn from the foot of the tower and the hydrogen from the top of the tower. The hydrogen may be used as fuel or for other purposes; the mercury is recirculated through the cells. The caustic solution is available as feed for a caustic concentrating evaporator, or for other purposes.

Brine used in the cells is also circulated. Spent brine is treated to remove the dissolved chlorine, fortified with fresh salt, filtered, and returned to the cells.

Each DeNora cell uses about 1.7 tons of salt and 3100 kwhr of energy per day and produces about a ton of chlorine, a ton and a half of caustic soda, and 10,000 ft^3 of hydrogen.

The plant was completed in 1952 and given a brief trial run. It has remained idle to date, but the Government has now invited bids for sale or lease of the plant. Plant capacity is about 225 tons of chlorine per day.

U. S. Industrial Chemicals Company, Huntsville, Alabama

This company is a division of the National Distillers Products Company and at present leases the Government-owned chlorine-caustic plants at the Redstone Arsenal, Huntsville, Alabama. There are two of these plants located about three miles apart in the arsenal area. The plants were originally built for the Chemical Corps during World War II. After the war the plants were leased, first to the Solvay Process Company and then to the Algonquin Chemical Corporation whose assets were purchased by the National Distillers Products Corporation in 1952.

Each of the plants is equipped with 200 Hooker "S" chlorine cells having an annual production capacity of 18,250 tons of chlorine and 20,500 tons of caustic soda. Salt from Louisiana is purified at the plant and used to make the brine fed to the cells. The chlorine is dried, liquified, and shipped in tank cars. Caustic soda is concentrated to a 50% solution and likewise shipped. By-product hydrogen is wasted at present.

Consumption of energy and materials per ton of chlorine is 3000 kwhr, 1.75 tons salt, and 50 lb of sulfuric acid. It requires about 5.5 tons of steam for the concentration of a ton of caustic soda.

In fiscal 1953 the company had a peak power demand of 15,000 kw and used some 59 million kwhr at an average monthly load factor of 83%.

Pennsylvania Salt Manufacturing Company, Calvert City, Kentucky

In 1948 this company began the construction of a small chemical plant at Calvert City, Kentucky. In the next few years a number of other companies, notably, the Pittsburgh Metallurgical Company, the B. F. Goodrich Rubber Company, and the National Carbide Company (Airco) built nearby plants; Calvert City is fast becoming a notable chemical manufacturing center.

The Pennsalt chlorine-caustic plant was added to the company's initial installations and got into production in the spring of 1953. The present production capacity is some 50 tons of chlorine and 55 tons of rayon-grade caustic per day, along with about half a million cubic feet of hydrogen. It is one of the four plants in the United States now using DeNora cells.

The DeNora cell has been described in detail in many technical articles (1), as has also the Mathieson mercury-sodium amalgam cell (2). At the Pennsalt plant the cell is 40 ft long and is lined with cyanite granite imported from Italy. Chlorine lines are of Haveg and hydrogen lines of rubber. Part of the hydrogen is used in the production of hydrogen chloride supplied to the nearby Goodrich plant.

Expansion now under way will soon enable the plant to use power at the rate of 160 million kwhr per year.

Velsicol Corporation, Memphis, Tennessee

The Velsicol Corporation of Chicago, a division of the Avery Corporation, operates a chlorine-caustic plant at Memphis and uses the chlorine to produce insecticides.

The plant was expanded in 1953 to a capacity reported to be 44 tons of chlorine and 55 tons of caustic per day. By-product hydrogen will be piped to a neighboring plant for the hydrogenation of fats. The Velsicol plant has a power demand of 7500 kw and in fiscal 1953 used some 34 million kwhr of energy.

Electroplating Plants

Electroplating equipment is in use in a number of plants in the region but is a minor part of a large plant. A typical example of this sort is the electroplating equipment in the Rockwell Manufacturing Company plant at Tupelo, Mississippi, where certain machine parts are chromium plated.

Southern Electroplating Company, Memphis, Tennessee

The only large electroplating operation in the region is carried on by the above-named concern. The company has two plants in Memphis. Its Madison Street plant uses six 1500-amp rectifiers and includes a manually operated plating line for zinc plating. The plant also includes a job shop for the plating of copper, nickel, chrome, gold, and silver.

The main installation in the company's Kentucky Street plant is a Udylite full automatic plating machine for volume zinc plating, a Udylite six station rotary full automatic anodizing machine, and two Udylite zinc barrel plating machines. Also installed in the plant is an electrically heated copper brazing furnace in which a temperature of 2150°F can be maintained in a controlled atmosphere in an oven 3 ft wide and 13 ft long.

At present, one of the plants uses about 22,000 kwhr per month and the other 60,000 kwhr per month. In fiscal 1953 the two plants used 701,000 kwhr of electric energy.

Hydrogen-Oxygen Plants

Hydrogen is, of course, produced as a by-product in all the chlorine-caustic plants in the region and in some instances this hydrogen is being used for the hydrogenation of liquid fats.

There are two hydrogenation plants in Chattanooga that do not use by-product hydrogen. One of these generates hydrogen by the steam-ferrosilicon process. The other, Wilson and Company, uses electrolytic hydrogen produced at the company's plant under an arrangement with the National Cylinder Gas Company. The latter concern supplies Wilson and Company with hydrogen and markets the co-product oxygen. The connected load of the electrolytic equipment is about 1000 kw.

Electromanganese Plants

Electro Manganese Corporation, Knoxville, Tennessee

Electro Manganese Corporation operates two commercial electrolytic manganese plants, the only ones in the region. A small plant was first placed in operation in 1939 and by January 1941 electromanganese was being delivered in commercial quantities. The plant was expanded on three occasions, and by January 1951 it was producing slightly over ten short tons of pure manganese per day.

Demand for electromanganese was accelerated when Government restrictions were placed on civilian consumption of nickel. Stainless steel producers found that they could substitute electromanganese for nickel in certain types of stainless steel, and late in 1953 a new 10-ton per day plant was placed in operation by the Electro Manganese Corporation to meet increased demand.

Both plants operate on imported high grade oxide ores brought in through the ports of New Orleans, Mobile, Norfolk, and Baltimore. Principal sources of ore are Africa, South America, and Cuba. At one time or another, manganese ores from every major producing country in the world have been used.

Both plants use the sulfate electrolyte process. Oxide ores are reduced to manganous oxide in electrically heated rotary kiln-type furnaces. Raw electrolyte is prepared by leaching the reduced ores with spent electrolyte returned from the cells. Iron is precipitated with the gangue in the leach tanks, after which the slurry is pumped to Dorr thickeners for clarification. Dorr underflow is filtered and combined with overflow. After *p*H adjustment, ammonium sulfide is added to remove nickel, copper, and other heavy metals which would interfere with manganese deposition. After further filtration and clarification steps, sulfur dioxide is added and solution is ready to be pumped to the cells. Manganese is deposited on stainless steel cathodes in diaphragm cells. Both rectifiers and motor-generator sets are used to supply direct current to the cell rooms. Total power consumption is about 5 kwhr/lb of metal produced. At periodic intervals, cathodes are removed from the cells, washed thoroughly, and dried. Manganese is stripped from the cathodes by flexing them in a jig. The product flakes off the cathodes in the form of chips about 1/16 in. thick. It is packed in steel drums for shipment.

Almost fifty million pounds of electromanganese have been produced and sold since the company started operations. From 60–75% of the product goes into stainless and alloy steel production. The balance is consumed by nonferrous alloy producers and by the chemical industry.

In fiscal 1953 the plants used some 37 million kwhr. This was before the new 10-ton per day plant came on the line.

Phosphorus-Producing Plants

The presence of natural rock phosphate deposits in Middle Tennessee and the availability of relatively cheap power from the TVA power net led to the installation of phosphorus-producing plants in the region, beginning in 1934. At present there are four such plants, listed below in the order of their initial operation.

Plant	*Initial operation*	*Approx. annual capacity as of 1953 (tons)*
TVA at Wilson Dam, Alabama	1934	30,000
Monsanto Chemical Company	1936	75,000
Victor Chemical Works	1938	34,000
Shea Chemical Corporation	1953	20,000

TVA Plant at Wilson Dam, Alabama

The TVA has built and operated two large-scale furnaces of circular horizontal cross section and six of approximately rectangular horizontal cross section. Most of the six rectangular have been remodeled extensively from time to time. General features and dimensions of the largest (nominally 12,500 kw) of the rectangular furnaces were given in an article appearing in this JOURNAL (3). The second of the circular furnaces, installed in 1950, incorporated a novel feature in phosphate-smelting furnaces in that the crucible of the furnace was rotated slowly. This furnace and its performance have been described in two published articles (4, 5). A lengthy report covering TVA experience with phosphate-smelting furnaces is to be found in TVA's Chemical Engineering Report No. 3, and an article dealing with the design of such furnaces has been published by Curtis (6).

The six furnaces currently in use at the TVA plant are

usually operated at the following power loads: furnaces 1–4 in range 7000–7700 kw, average about 7380 kw; furnace 5 about 10,300 kw; and furnace 6 about 11,200 kw, or a total of some 51,000 kw. Based on the assumption that it requires about 11,750 kwhr per ton of elemental phosphorus recovered as such, the theoretical output of the plant, if operated continuously 365 days per year, would be some 38,000 tons of phosphorus annually. Actually, of course, no such operation is possible in a phosphate-smelting plant. Shutdown periods must be scheduled for major repairs and for periods of power shortage; and minor interruption will occur during scheduled operating periods due to an occasional broken electrode, minor repairs, or to interruptions in the gas-handling equipment serving the furnaces. In fiscal 1953 the six TVA furnaces operated 95.2% of the scheduled time and about 80% of the calendar time of the year. The practical capacity of the plant may therefore be stated as about 30,400 tons of phosphorus per year. In the event of a war and a great need for phosphorus, the plant could probably produce more than 38,000 tons by using overtime on repairs and by overloading the furnaces.

Monsanto Chemical Company's Phosphorus Plant Near Columbia, Tennessee

The Monsanto Chemical Company acquired a controlling interest in the Swan Corporation in 1933 and in 1935 absorbed this concern and its subsidiary, the Federal Phosphorus Company. The furnaces that the Swan concern had acquired at Anniston, Alabama, were originally built to produce ferromanganese during World War I. They were changed to ferrophosphorus production units by Swan, at first with little or no attempt to recover the elemental phosphorus that escaped conversion to ferrophosphorus. This created an intolerable air pollution problem. As a result of the installation of phosphorus recovery equipment, phosphoric acid eventually became the main product of the plant and ferrophosphorus a by-product. The proportion of the total phosphorus that went into ferrophosphorus could be varied from the minimum unavoidably formed from the iron present in the raw phosphate to any desired proportion by the expedient of adding iron filings, turnings, or scrap to the furnace charge.

At the time Monsanto took over the plant it was equipped with four 3000-kw furnaces. The Monsanto concern immediately began acquiring phosphate properties in Middle Tennessee and in 1936 put into operation a three-furnace phosphate-smelting plant in Maury County near Columbia, Tennessee.

The three furnaces initially installed had a nominal rating of 8000 kw each. Later it proved feasible to operate these furnaces at considerably higher loads.

The three electrodes per furnace were spaced at the corners of a triangle. The furnace shell was hexagonal in horizontal cross section, with three long and three short sides, but the shell was lined so as to form, in horizontal cross section, a triangle with rounded corners. Carbon electrodes 35 in. in diameter were used at first.

The peak load of the Monsanto plant did not exceed 37,000 kw in the period 1936–39, and, since some power was used in the plant elsewhere than on the furnace, presumably the three original furnaces were operated near their nominal capacities. In fiscal 1940 the peak power demand increased to about 50,000 kw when a fourth furnace, considerably larger than the three original ones, was added. A fifth furnace was added during fiscal 1949, increasing the peak demand to 75,000 kw. In fiscal 1951 the peak power demand again jumped, this time to 120,000 kw, because of the addition of a sixth furnace and presumably because it had been found possible to operate some of the earlier-installed furnaces at a higher load than the nominal furnace rating. In fiscal 1953 the peak demand was 120,000 kw and the energy used was 895 million kwhr, with an average monthly load factor of 96%. If one guesses that 90% of this energy went into the furnaces and again guesses that the Monsanto furnaces require 12,000 kwhr per ton of phosphorus recovered (according to data published in 1950 by a Monsanto employee, the energy consumption was then 13,000 to 14,000 kwhr per ton of phosphorus) it appears that Monsanto's phosphorus production capacity at the Tennessee plant is about 75,700 tons and the actual production in fiscal 1953 was about 67,125 tons. In the August 2, 1952 issue of *Chemical Week*, the annual production capacity of Monsanto's six furnaces in Tennessee is given as 65,000 tons. Monsanto has also a phosphate-smelting plant at Soda Springs, Idaho, where 25,000-kw furnaces have been installed, and the company is now the largest phosphorus producer in the world.

The phosphate used in the plant comes from both Florida and Tennessee. The Tennessee matrix is mined by the company from its properties near the plant, beneficiated by hydrometallurgical methods, and prepared for furnace use by sintering in a standard sintering machine.

Shea Chemical Corporation Plant Near Columbia, Tennessee

This plant was put into operation in fiscal 1953. It is a single-train plant consisting of a phosphate drier, a nodulizing kiln, a drier for coke and silica, a phosphate-smelting furnace of 26,000-kw nominal capacity, a phosphoric acid plant, and a dicalcium phosphate plant.

The electric furnace is modeled after TVA Furnace No. 6 but expanded to about twice the capacity of the TVA unit. Graphite electrodes 35 in. in diameter are used. The present power load of the plant is 33,000 kw and the furnace is stated to have an annual production capacity of 20,000 tons of elemental phosphorus. The practical annual capacity is probably somewhat less than this.

Furnace offgases are cleaned in an electrostatic precipitator. The acid plant consists of a graphite combustion chamber, a cooler, a hydrator, and a stainless steel Venturi-type fume scrubber wherein phosphoric acid of 70–80% concentration is used to recover the acid mist from the waste gases.

The dicalcium phosphate plant includes a funnel-type continuous mixer in which the ground limestone is introduced at the top of the funnel in which the acid is entrained in a stream of air and blown tangentially into the throat of the funnel. The mixture then passes through a paddle-type mixer and is conveyed to storage. The dicalcium phosphate recovered from the storage pile is dried, ground, and sized for shipment. The dicalcium phosphate plant has a production capacity of 250 tons per day.

Victor Chemical Works Plant Near Mt. Pleasant, Tennessee

The Victor Chemical Works began producing phosphorus in an experimental blast furnace unit at the company's Chicago plant in 1924. In 1929 the company constructed a small commercial plant of this kind near Nashville, Tennessee. This plant is of some historical interest not only because of the blast furnace method used, but also because, for the time, lower grades of rock phosphate than normally prepared for fertilizer manufacture were used. The furnace charge was briquetted. Since the phosphorus content of furnace offgases was low, and the gases carried a relatively large burden of dust, the gas-cleaning equipment necessary to secure ele-

mental phosphorus of chemical grade was large, elaborate, and costly.

After electric power became available at low rates in the Tennessee Valley the company turned to the electric furnace method and built a phosphate-smelting plant near Mt. Pleasant, Tennessee, in 1937 and put the first furnace into operation in 1938. The initial furnaces in this plant were modeled on the TVA furnaces then in operation at Wilson Dam, Alabama. The second furnace at the plant went on the line late in 1939, a third early in 1940, and a fourth late in 1940, the last in anticipation of a military demand for phosphorus. At first a part of the output of the fourth furnace was sold to the TVA for fertilizer production, but the whole output was diverted to military use in 1942.

The company's Mt. Pleasant plant has been operated at a high load factor since 1940. The nominal capacity of the four furnaces as originally designed was 7500 kw each, but through improvements over the years the four-furnace load has been built up. In fiscal 1953 the peak load of the Mt. Pleasant plant was 52,000 kw, with an average monthly load factor of 98%. Actual energy consumption for the year was 393 million kwhr. Assuming that 90% of the plant energy consumption went to the furnaces and that it required 12,000 kwhr per ton of phosphorus recovered, production was in the neighborhood of 29,000 tons. Plant capacity is presumably somewhat greater than this, perhaps near 34,000 tons.

Initially the phosphate for the furnace charge was nodules prepared by one of the neighboring fertilizer companies, using the techniques developed by the TVA at Wilson Dam, Alabama, but late in 1939 the company put the first of its own three nodulizing kilns into operation. The company pioneered in the development of equipment to scrub the fluorine-carrying offgases from its nodulizing kiln and put the first such scrubber into operation in 1941. There is no attempt to recover fluorine compounds in marketable form. Water is used as the absorbent in the towers. The resultant acid solution is neutralized with lime, and the solids then separated in Dorr thickeners and discarded.

Phosphorus produced at the Mt. Pleasant plant is shipped to other of the company's plants for conversion to phosphorus compounds.

In 1947 the Victor Chemical Works put a phosphate-smelting furnace into operation in Florida and in 1950 began construction of a phosphate-smelting plant in Montana that is equipped with two 25,000-kw furnaces.

Calcium Carbide Plants

There are two plants in the region equipped to produce calcium carbide, but one of them, constituting a part of the old U. S. Nitrate Plant No. 2 at Wilson Dam (now the TVA Chemical Plant), has not been operated since World War II.

TVA Carbide Furnaces at Wilson Dam, Alabama

U. S. Nitrate Plant No. 2, built during World War I, was a cyanamide plant and included twelve carbide furnaces rated at 6000 kw each. Only a few of the furnaces were operated in a trial run of the plant in 1919.

After the TVA took over the plant, six of the carbide furnaces were removed to make room for phosphate-smelting furnaces. The other six carbide furnaces remained intact. During World War II, when acetylene was needed for synthetic rubber production, the TVA placed the six furnaces in operation in 1943 and during the war period produced 242,521 tons of carbide. The furnaces were thereafter shut down and have remained idle. During the fiscal year 1944 some 107,000 tons of carbide were produced and this presumably represents about the reserve available capacity in the Wilson Dam plant.

National Carbide Company, Calvert City, Kentucky

(A Division of Air Reduction Company, Inc.)

The Calvert City plant of this company built the second of the large electroprocess plants in this fast-growing industrial center. Construction was begun in 1951 and initial production of carbide attained early in 1953. The cost of the original two-furnace carbide and acetylene plant is said to be ten million dollars. The initial furnaces each have a capacity of 75,000 tons of carbide per year and by March 1954 the company expects to bring in two other furnaces of like capacity in connection with an eight million dollar expansion of the plant, bringing the total carbide capacity to 300,000 tons per year. After the expansion is completed it can use power at the rate of about one billion kwhr per year.

The two 30,000-kw furnaces, the first carbide furnaces of this type to be built in the United States and the largest carbide furnaces in the world today, are of the rotating crucible type developed by the Norwegian Elektrokemisk concern. Söderberg electrodes are used and the furnaces are tapped continuously into ingot molds carried on a slowly moving conveyor. Furnaces are of the closed type, rotated at some 50 to 100 hr/revolution; the by-product carbon monoxide is currently wasted by burning it.

Acetylene is piped from the acetylene generators to the nearby plant of the B. F. Goodrich Chemical Company.

The National Carbide Company acquired a 1500-acre tract of land around its Calvert City plant and has subdivided it into 15 plant sites, one of which is now occupied by the Goodrich plant.

Ferroalloy Plants

There are four plants in the region producing ferroalloys in addition to the iron foundries where alloys other than steel are made.

Southern Ferro Alloys Division, Tennessee Products and Chemical Corporation, Chattanooga, Tennessee

The Southern Ferro Alloys Company was organized in 1917 as a successor to the Chattanooga Electro Metals Company, and produced various grades of ferrosilicon. Over the years the plant was expanded and by 1944 it included five furnaces ranging in capacity from 1800–5000 kw. In addition to these, the Government had installed two 5000-kw furnaces in the plant. These were later purchased by the company. In 1947 the Southern Ferro Alloys Company was purchased by the Tennessee Products and Chemical Corporation and became a division of this corporation. The Tennessee Products and Chemical Corporation owns another plant in Chattanooga, known as its Alton Park plant, originally a coal carbonization unit, but later expanded to include the production of chemicals. Two 3500-kw ferrosilicon furnaces were also added to the Alton Park plant, and lately two 5000-kw ferromanganese furnaces were put into operation there. It is said that the company plans to consolidate all of its operations at this plant. It is estimated that when the electric furnace operations are consolidated the connected furnace load will be between 40,000 and 45,000 kw. In fiscal 1953 the two plants used 246 million kwhr at high monthly load factor. The new ferromanganese furnace will, of course, considerably increase the energy consumption above the fiscal 1953 figure.

Electro Metallurgical Company, Sheffield, Alabama

The Alabama works of this company, which is a division of the Union Carbide and Carbon Corporation, started operations in April 1940. Production capacity of the plant has been tripled since that date and the output is now (November 1953) some 8000 tons per month. Energy consumption for the smelting of raw ores currently amounts to about a million kwhr per day, and the consumption for the whole plant amounted to 464 million kwhr in fiscal 1953, with an average monthly load factor of 94%.

The company employs about 500 people at the Alabama plant and produces various grades of ferrosilicon, ferromanganese, silicomanganese, and zirconium alloy.

Pittsburgh Metallurgical Company, Calvert City, Kentucky

The Calvert City plant of this company went into operation in 1949, producing ferrochromium, ferrosilicon, and ferrochrome-silicon alloys, alloy pig iron, and similar products. In 1953 the power demand reached 63,000 kw and in fiscal 1953 the energy consumption was 284 million kwhr.

Montana Ferroalloys, Inc., Memphis, Tennessee

This company is a subsidiary of the Chromium Mining and Smelting Corporation of Chicago.

The Memphis plant went into operation early in 1952. It is equipped with three 7000-kw furnaces for the production of chromium and silicon ferroalloys. Normally only two of the furnaces are operated, producing some 12,000 tons of alloys per year. If the two furnaces were operated at full load continuously, the annual energy consumption would be 122.6 million kwhr. Actual energy consumption is probably in the neighborhood of 75% of the theoretical, i.e., some 92 million kwhr annually.

The alloys are shipped to steel mills or to the parent company's plant in Chicago which produces and markets "Chrom-X," "Sil-X," and "Chrom-Sil-X."

Electrodes

National Carbon Company, Columbia, Tennessee

The National Carbon Company, Inc., a division of the Union Carbide and Carbon Corporation, established a plant near Columbia, Tennessee, in 1937 for the manufacture of furnace electrodes. This plant was greatly expanded recently and is now the world's largest electrode manufacturing plant. Both carbon and graphite electrodes are produced. The company used some 141 million kwhr in fiscal 1953, most of this energy going into the resistor-type furnaces in which graphite electrodes are made.

Foundries

There are at least two foundries in the region that make enough use of electric furnace melting to be classed as electroprocess operations, and, in one of these, every operation uses electric energy as a source of heat.

Ross-Meehan Foundries, Chattanooga, Tennessee

This foundry is probably unique in the United States in that all its ovens, furnaces, etc., are electrically heated. These include melting furnaces, core ovens, and heat-treating and annealing furnaces. In the two melting furnaces both carbon steel and several alloy steels are produced, including steel for armor plate. Seven heat-treating furnaces are used for normalizing carbon steels and for homogenizing armor steels, the latter operating at temperatures up to 2150°F. The company also produces Meehanite alloy castings which are heat-treated for normalization and relief of stresses. Electric energy consumption in fiscal 1953 was [illegible] million kwhr.

Knoxville Iron Company, Knoxville, Tennessee

This is an old company in Knoxville, claiming 1868 as the date of establishment. Of course, it used no electric energy at that date nor until long after. At present the company uses electric furnaces for melting scrap and for alloying. It uses gas heat for some of its operations. Electric energy consumption in fiscal 1953 was some 13 million kwhr.

Miscellaneous Plants Using Electric Furnaces Incident to Manufacturing

Only plants using more than two million kwhr annually for all purposes are listed. The largest energy consumer in the group uses about 24 million kwhr annually.

Aladdin Radio Industries, Inc., Nashville, Tennessee.—This company is a subsidiary of Aladdin Industries, Inc., also located at Nashville. Electrically heated ovens are used in processing powdered metals in the manufacture of electronic circuit parts.

American Lava Corporation, Chattanooga, Tennessee.—This concern, a subsidiary of the Minnesota Mining and Manufacturing Company, manufactures ceramic articles for use in electrical and other industrial equipment. Silicon carbide resistor furnaces are operated at about 1400°C for firing titanate ceramics. Nichrome resistor furnaces are used in metallizing ceramics, and dielectric heaters are used in drying ceramics.

Cleveland-Tennessee Enamel Company, Cleveland, Tennessee.—Electrically heated enamel driers and baking ovens are in use, with a total demand load of some 2000 kw. The company's chief product is porcelain enamel stove parts.

Crane Company, Chattanooga, Tennessee.—Crane manufactures enamel ware of various sorts, using electrically heated ovens and muffles.

Ferro Corporation, Nashville, Tennessee.—This company manufactures ceramic articles, frit, fiberglass, etc., using electrically heated equipment.

Florence Stove Company, Lewisburg, Tennessee.—Two electrically heated enameling ovens are in use at this plant, one of 1000 kva and the other of 1368 kva capacity.

Gray & Dudley Company, Nashville, Tennessee.—Products manufactured in the company's Nashville plant include gas and electric ranges, electric water heaters, gas furnaces, coal stoves, etc. A number of small (88-kw) enamel driers are used along with three 275-kw flat bed enamel baking furnaces. Paint enamel is baked in a 17.6-kw oven.

The Murray Manufacturing Company, Murray, Kentucky.—This company is a producer of gas and electric ranges. An electric furnace is used in fusing porcelain enamel for stove parts.

Polynesian Arts, Inc., Mayfield, Kentucky.—An electrically heated tunnel kiln is used in firing of decorated pottery.

Temco, Inc., Nashville, Tennessee.—Temco uses both gas-fired and electrically heated enameling furnaces in producing gas heaters and stove parts. The company also uses small induction-heated furnaces for heating tubing preliminary to forging.

New Electroprocess Plants in the Region

A number of new plants using electroprocess operations are now under construction in the region. These are:

Cramet, Inc.—This company is a subsidiary of the Crane Company. It is building a plant at Chattanooga for the

production of titanium under a U. S. Government loan, certificate of necessity, and contract for purchase of at least a part of the output. Presumably the Kroll process will be used. In this process titanium tetrachloride is first prepared and then reduced by magnesium in a fused-salt bath. The resulting magnesium chloride is separated from the sponge titanium by distillation in a vacuum.

The process makes use of electrical heating to such an extent as to be classified as a partially electrothermal operation.

Judging by the announced power consumption contemplated in the initial operation of the plant, the necessary chlorine and magnesium will be purchased. It is likely that any large plant using the Kroll process will eventually find it economical to install magnesium-chlorine electrolytic cells to permit recycling of the magnesium and chlorine in the process. Such an addition to the Cramet plant would greatly increase the energy required locally per pound of titanium produced.

Oldbury Electro-Chemical Company.—This concern is building a plant near Columbus, Mississippi, for the production of sodium chlorate and other chemicals. Initial operation is scheduled for 1954. The plant is said to cost $3,500,000 and to have an annual production capacity of 12,500 tons of chlorate.

E. I. du Pont de Nemours and Company.—A second titanium plant, financed by the Government, is to be built by du Pont near Waverly, Tennessee, adjacent to the TVA's New Johnsonville steam-electric power plant.

Power Supply in the Tennessee Valley Region

As of June 30, 1953 the installed capacity serving the TVA power system was 5,102,985 kw and net generation in fiscal 1953 was 23,744,919,465 kwhr. The system also handled an additional 3,602,771,802 kwhr received from neighboring power systems, making a total of 27,347,691,267 kwhr. Deducting system losses, power returned to neighboring power systems, power furnished Alcoa under contract involving Alcoa power plants, and TVA incidental uses, the net power sales in fiscal 1953 amounted to 23,678,681,109 kwhr.

Of the net generation cited above for fiscal 1953, hydro installations furnished 58.7%, coal-burning power plants 39.8%, and plants using gas or oil 1.5%. This situation is changing rapidly as the very large steam-electric plants that TVA is building come into production. As these plants are completed and the few hydroelectric units now under construction come on the line, the generating capacity will increase to some 6.1 million kw by the end of fiscal 1954, to 8.8 million kw at the end of fiscal 1955, to 9.9 million kw at the end of fiscal 1956, and when all units now under construction are on the line in fiscal 1957 the system will reach a capacity of about 10 million kw. By 1957, the AEC and other directly served Government plants will probably use about one-half of the total energy.

It is obvious from the above statement that power consumption in the region is growing rapidly. Increased demand comes from all segments of the power consuming group, i.e., Government plants, industrial plants, commercial establishments, and domestic consumers. The TVA estimates that some 750,000 kw capacity must be added to the system annually to meet these demands without any allowances for increases in the requirements of the Government plants. This means that a large new steam-electric plant must be added annually to meet the needs for the years immediately following 1957. Since it requires about three years from time of authorization to complete a large steam-electric plant, construction beyond that already in progress must be begun in the near future if industrial development in the region is to continue. There will probably be a few more small hydroelectric plants built on the tributaries of the Tennessee but the main reliance will rest on steam-electric plants. The environment for such new industrial plants is favorable in the region, and given adequate power there is no reason to doubt that the industrial growth will continue.

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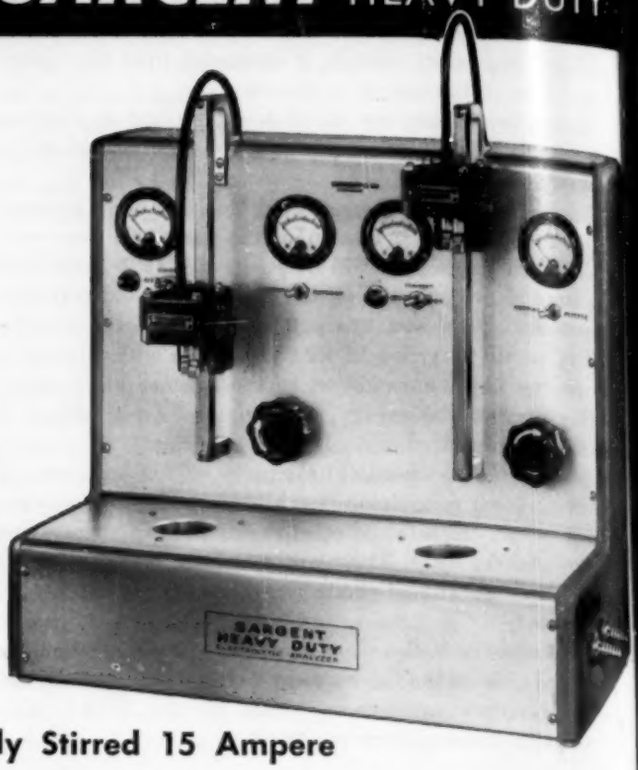

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The Heavy Duty has recessed wells to hold the sample beakers, wells being 6¼" deep, designed to contain 250 ml electrolytic beakers. The wall of each well serves as an inner wall of the water jacket, for use in either heating or cooling. Two serrated nipples for rubber tubing connections for cooling or heating water are mounted on the right end casting. In plain copper analysis, 1 gram of copper may be deposited in 15 minutes with an accuracy of approximately 0.05% without the necessity of special techniques.

All electrolytic analyzers accommodate electrodes having shaft diameters no greater than 0.059 inch. Stainless steel spring tension chucks permit quick, easy insertion of the electrodes and maintain proper electrical contact. On the Heavy Duty Analyzer, the cathode chuck is eccentrically mounted, providing adjustability to accommodate electrodes up to 50 mm diameter. Special Sargent high efficiency electrodes are available for both analyzers.

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carbon tetrachloride gave a wave at −1.01 volts in 75% dioxane and 0.10*M* lithium chloride. It is obvious that the medium has a profound effect upon reduction, and that a more systematic investigation of the influence of the medium on the half-wave potential is needed. With more data on polarographic reduction of organic halogen compounds it should eventually be possible to formulate the reaction mechanism.

The present investigation deals with polarographic reduction of carbon tetrachloride in mixtures of methanol and water, *n*-propanol and water, acetone and water, and a (1:1) mixture of benzene and methanol, using various inorganic salts and tetraalkylammonium halides as the supporting electrolyte. In a few instances, the effect of ionic strength on the half-wave potential and the influence of concentration of carbon tetrachloride on the wave-shape are also reported. Polarographic reduction of chloroform was investigated briefly in methanol-water mixtures to allow comparisons to be made with the second wave of carbon tetrachloride.

Experimental

Chemicals.—Mallinckrodt's "analytical reagent" grade of carbon tetrachloride, chloroform, methanol, acetone, and benzene was used without further purification. The *n*-propanol was Eastman white label. All the salts used were polarographically pure.

Apparatus.—Measurements of polarographic waves were made manually with a Sargent Model XII Polarograph. In some cases a Sargent Model XXI Recording Polarograph was used to study wave-shapes. Applied potentials were measured at each setting against a potentiometer. All potential measurements were made against an external saturated calomel electrode (S.C.E.) at 27°C. The S.C.E. was connected to the sample cell by means of an agar bridge. Potassium chloride was used as the salt in the bridge for runs with an inorganic salt as supporting electrolyte. When using a tetraalkylammonium halide as electrolyte, the last part of the bridge was made of tetraethylammonium bromide. Resistance of the circuit was measured with a Serfass Conductance Bridge, Model RC M 15. The capillary used had a value for m of 1.46 $mg^{2/3}/sec^{1/6}$ at open circuit in 0.1*M* potassium chloride.

Preparation of the solutions.—The supporting electrolyte was dissolved in 25 ml of a mixture of the organic solvent and water. Carbon tetrachloride was added in form of 0.50 ml of a 6.9×10^{-2} *M* solution in the pure organic solvent. Since this investigation was primarily concerned with the effect of the medium on the half-wave potential, no measurements were taken to determine exact concentrations of organic halide in solutions.

Procedure.—Nitrogen was passed through a portion of the supporting electrolyte before going through the solution in the polarographic cell. Deaeration of 30 min for predominantly organic solutions and 15 min for predominantly aqueous solutions was found to be sufficient to remove oxygen. Then, 0.50 ml of the stock solution of the alkyl halide was added and the mixture flushed for an additional period. In the pure organic solvents one could flush for several minutes without a significant decrease of concentration of the alkyl halide, whereas in water only a few seconds of degassing was possible, owing to the high volatility of the alkyl halide in this medium.

All the data were corrected for residual current as obtained from a blank (prepared in a similar way by adding 0.50 ml of pure organic solvent) and for *IR*-drop. Unless otherwise stated, experiments were run at a head of mercury of 78 cm, and the solutions were 0.05*M* in supporting electrolyte.

Results

Effect of Organic Solvents on Half-Wave Potentials of Carbon Tetrachloride

Table I gives the half-wave potential for the first wave of carbon tetrachloride in a series of methanol-water mixtures. With all salts studied, changing from water to 20% methanol had little or no effect on the half-wave potential. Beyond 20% the half-wave potential rapidly became more negative and then more or less leveled off, depending on the supporting electrolyte, at very high concentrations of organic solvent.

The second half-wave potential (Table II) was also shifted to more negative values by addition of methanol; the effect was, however, less pronounced. In all mixtures investigated, the second half-wave potential of carbon tetrachloride was practically

TABLE I. *Effect of the concentration of methanol and the nature of the 0.05M supporting electrolyte on half-wave potentials vs. S. C. E. of the first wave of carbon tetrachloride. Values are for* $-E_{1/2}$

Vol. ratio methanol/water	$LiNO_3$	LiCl	LiBr	KI	$(CH_3)_4NBr$	$(C_2H_5)_4NBr$	$(CH_3)_4NI$	$(C_3H_7)_4NI$	$(C_4H_9)_4NI$
Methanol	1.09	1.10	1.08	1.08	0.89	0.82	0.92[a]	0.87	0.88
5:1	0.95	0.95	0.95	0.95	0.82	0.74	0.81		0.74
2:1	0.78	0.80	0.78	0.79	0.70	0.62	0.70	0.65	0.64
1:1		0.59	0.60	0.64	0.58	0.50	0.61		0.59
2:3	0.46	0.47	0.48	0.59	0.46	0.44	0.57	0.57	0.57
1:4	0.35	0.35	0.40	0.54	0.40	0.37	0.53		0.53
Water	0.35	0.35	0.40	0.53	0.40	0.37	0.53		0.53

[a] A saturated solution, less than 0.05*M*, was used.

TABLE II. *A comparison of half-wave potentials (vs. S.C.E.) for chloroform with that for the second-wave of carbon tetrachloride in methanol-water mixtures containing 0.05M electrolytes. Values are for* $-E_{1/2}$

Vol ratio CH_3OH/H_2O	$(CH_3)_4NBr$		$(C_2H_5)_4NBr$		$(CH_3)_4NI$		$(C_3H_7)_4NI$		$(C_4H_9)_4NI$		$(CH_3)_4NCl$ CCl_4	LiCl CCl_4	KI CCl_4
	CCl_4	$CHCl_3$	CCl_4	$CHCl_3$	CCl_4	$CHCl_3$	CCl_4	$CHCl_3$	CCl_4	$CHCl_3$			
CH_3OH	1.64	1.62	1.73	1.72	1.66[a]				1.90				
5:1	1.65	1.65	1.72	1.72	1.64	1.65			1.89	1.91			
2:1	1.64	1.64	1.68	1.68	1.63	1.63	1.75	1.76	1.84	1.84			
1:1	1.60	1.60	1.62	1.63	1.60	1.60			1.77				
2:3	1.57	1.57	1.59	1.59	1.57	1.58	1.65	1.66	1.73	1.72			
1:4	1.54	1.54	1.53	1.54	1.55	1.55			1.68	1.68	1.54	1.71	1.72
H_2O	1.53	1.54	1.50	1.51	1.53	1.53			1.65	1.65			

[a] A saturated solution, less than 0.05*M*, was used.

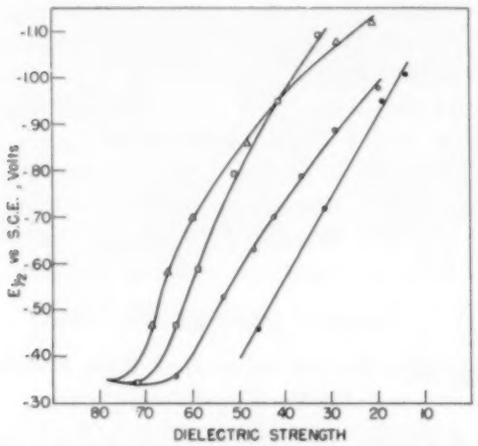

FIG. 1. Half-wave potential of the first wave of carbon tetrachloride as a function of the dielectric strength of mixtures of organic solvents with water. Electrolyte 0.05*M* lithium chloride. □—methanol-water; △—*n*-propanol-water; ○—acetone-water; ●—dioxane-water [data for dioxane solutions are taken from reference (11)].

identical with the first half-wave potential of chloroform, in agreement with previous observations (2, 10).

The very large shift with change in solvent for the first half-wave potential made it desirable to investigate the reduction in other media. Therefore, studies were made on *n*-propanol-water mixtures and on acetone-water mixtures; Fig. 1 shows the observed half-wave potential vs. the dielectric strength (12) of the solvents (without added electrolyte). As with methanol-water mixtures, reduction became more difficult at higher concentrations of organic solvent. One might have expected methanol and propanol solutions of the same dielectric strength to give the same half-wave potential,[3] but this was not the case. It is difficult to state what effect, if any, the capillary activity of the alcohols has on the half-wave potential.

The apparent numbers of electrons involved in the reaction, α, were calculated from the equation of the waves.

[3] Strictly speaking, solvents should only be compared at zero ionic strength, but the effect of ionic strength appears to be the same in both solutions.

$$E = E_{1/2} + \frac{0.06}{\alpha} \log \frac{i_d - i}{i}$$

In general, α-values of the first wave of carbon tetrachloride (Fig. 2) decreased markedly with increasing methanol concentration up to about 60% methanol, while at concentrations above 60% α increased slightly. Only with tetrabutylammonium iodide as electrolyte did α decrease throughout the region. Fig. 3 gives α of the second wave of carbon tetrachloride as a function of methanol concentration.

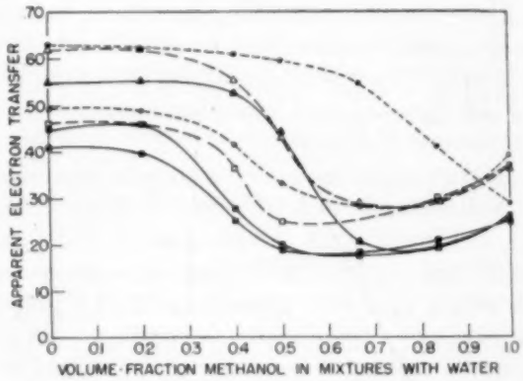

FIG. 2. α-values for the first wave of carbon tetrachloride as a function of methanol concentration and nature of the 0.05*M* electrolyte. ■—LiCl; ◩—LiBr; ▲—KI; □—$(CH_3)_4$NBr; △—$(CH_3)_4$NI; ○—$(C_2H_5)_4$NBr; ●—$(C_4H_9)_4$NI.

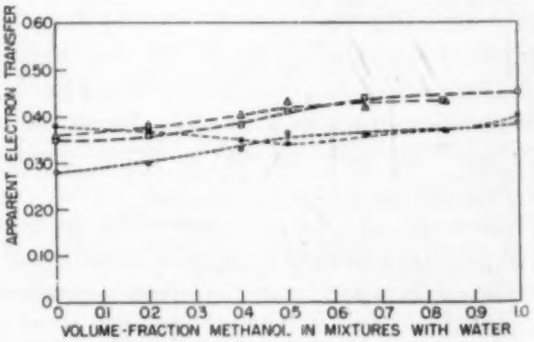

FIG. 3. α-values for the second wave of carbon tetrachloride as a function of methanol concentration and nature of the 0.05*M* electrolyte. □—$(CH_3)_4$NBr; △—$(CH_3)_4$NI; ○—$(C_2H_5)_4$NBr; ●—$(C_4H_9)_4$NI.

TABLE III. *Half-wave potentials vs. S.C.E. of the first wave of carbon tetrachloride in (1:4) methanol-water mixtures containing 0.05M electrolytes*

Electrolyte	$-E_{1/2}$	Electrolyte	$-E_{1/2}$
LiCl	0.35	LiBr	0.40
KCl	0.35	$(CH_3)_4NBr$	0.40
NH_4Cl	0.35	$(C_2H_5)_4NBr$	0.37
$(CH_3)_4NCl$	0.34	KSCN	0.44
HCl	0.34	KI	0.54
LiOH	0.35	$(CH_3)_4NI$	0.53
$LiNO_3$	0.35	$(C_4H_9)_4NI$	0.53

Effect of Nature of Supporting Electrolyte and Ionic Strength on Half-Wave Potential

The most extensive investigation of the effect of supporting electrolyte on the half-wave potential of carbon tetrachloride was carried out in methanol-water mixtures where eight different electrolytes were studied. Data in Table I show clearly that in predominantly aqueous solutions the first half-wave potential is a function only of the anion of the supporting electrolyte. The same anion effect on the first half-wave potential in predominantly aqueous solutions was found with *n*-propanol-water mixtures and acetone-water mixtures. In high concentrations of methanol, the first half-wave potential of carbon tetrachloride does not depend upon which alkali salt is used as supporting electrolyte, but does depend upon the cation of the supporting alkylammonium halide. On the other hand, only a cation effect was observed for the second half-wave potential throughout the whole range of solvent mixtures (Table II).

In order to get further insight into the observed anion effect on the first half-wave potential in predominantly aqueous solutions, six additional electrolytes were investigated in the (1:4) methanol-water mixture (Table III). The *p*H had little or no effect, as shown by the constancy of the half-wave potential in going from a lithium hydroxide to a hydrochloric acid solution. Different chlorides, nitrates, and hydroxides gave the same half-wave potential, −0.35 volt, while other anions shifted the potential to more negative values. Iodides shifted it more than thiocyanates,[4] and these, in turn, more than bromides. Wave shape was also affected by anions, steepness increasing upon going from chlorides to bromides to iodides (Fig. 2).

As shown in Fig. 4, increasing the ionic strength of an alkali halide shifted the first half-wave potential to more negative values in predominantly aqueous solutions, and to more positive values in predominantly organic solutions. Different tetraalkylammonium halides produced a similar shift.

[4] It was difficult to get maximum-free waves in the thiocyanate solutions.

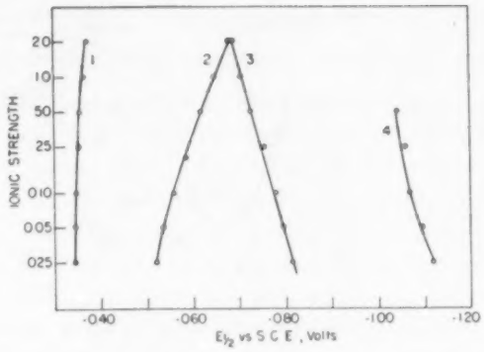

FIG. 4. Effect of ionic strength on the first half-wave potential of carbon tetrachloride. Curve 1—LiCl in a (1:4) methanol-water mixture; curve 2—KI in a (1:4) methanol-water mixture; curve 3—LiCl in a (2:1) methanol-water mixture; curve 4—LiCl in methanol.

The large iodide effect in the (1:4) methanol-water mixture is obvious from these curves. In pure methanol, however, increasing concentrations of iodide and chloride produced the same shift. For the second half-wave potential a shift to more positive values throughout the whole region from water to methanol was found with increasing ionic strength of different tetraalkylammonium halides.

Effect on Shape of Polarographic Wave of Concentration of Carbon Tetrachloride, Temperature, and Head of Mercury

Maxima often occurred on the first polarographic wave of carbon tetrachloride in predominantly aqueous solutions and thereby complicated the waves. Therefore, a series of experiments were carried out to get an idea of the factors governing occurrence of maxima. It was found that formation of maxima was favored at higher concentration of carbon tetrachloride, at longer drop times, and at higher temperatures.

Curves in Fig. 5 showing the effect of concentration of carbon tetrachloride and head of mercury, the latter used as a measure of the drop time, on the polarographic wave in a (1:4) methanol-water mixture, were obtained on the same sample. For one particular concentration of carbon tetrachloride, currents were measured at each potential setting with the mercury reservoir at different levels. After finishing one set of curves in this way, the solution was flushed for a few seconds to decrease the concentration of carbon tetrachloride, and a new set of curves obtained. Fig. 5 shows that in the region of the maxima, the current increased upon lowering the head of mercury, the reverse of the relationship for a diffusion-controlled process. When the concentration of carbon tetrachloride was very high, this rule was apparently not obeyed because curves for lower heads of mercury lay below curves for higher heads. However, polarograms obtained with a

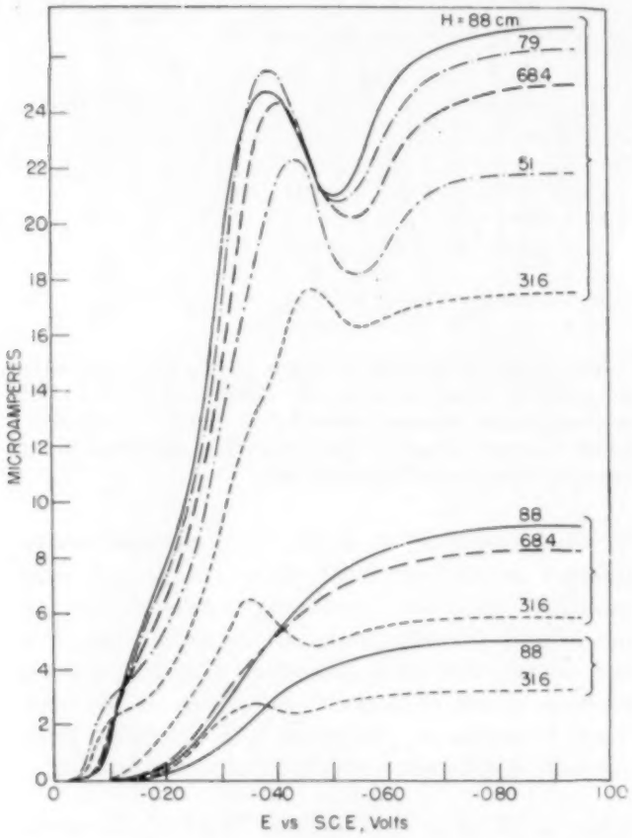

FIG. 5. Effect of concentration of carbon tetrachloride and the head of mercury on the polarographic wave in a (1:4) methanol-water mixture containing 0.05*M* lithium chloride. All curves within a given bracket were obtained at one particular concentration of carbon tetrachloride.

Sargent Model XXI Recording Polarograph on solutions of very high concentration of carbon tetrachloride showed that, in the region where the maxima occurred, the current-time curves for individual drops also had irregular shapes and went through one or two maxima. This "discharge," shown in Fig. 6, obviously prevented the current from attaining higher values.

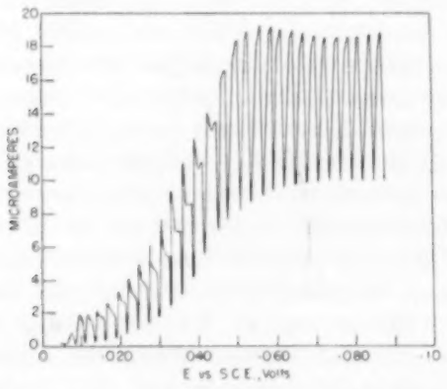

FIG. 6. First wave of carbon tetrachloride, at approximately five times the usual concentration, in a (1:4) methanol-water mixture containing 0.05*M* lithium chloride.

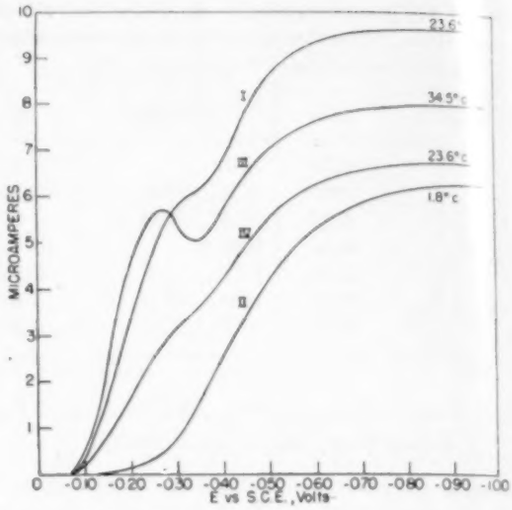

FIG. 7. Effect of temperature on the first wave of carbon tetrachloride in a (1:4) methanol-water mixture containing 0.05*M* lithium chloride. Numbers attached to the curves give the order in which the runs were made.

In an effort to determine whether or not an adsorption wave was involved, the temperature dependence of the maximum was investigated. A number of runs were carried out on the same sample in the order indicated by numbers attached to each curve in Fig. 7. In these runs, three times the usual concentration of carbon tetrachloride was used to accentuate changes in wave shape that accompany a change in temperature. Some carbon tetrachloride was lost when heating the sample for the high-temperature run as seen from a comparison of the values for the limiting current in the two runs at 23.6°C. In spite of this fact, it is clear that the size of the maximum increased with temperature. It is also interesting to note that no maximum occurred on the polarographic wave at 1.8°C. The possibility of suppressing the maximum with gelatin was also tried, but, in the usual concentration of 0.005% gelatin there was no effect.

In spite of these irregularities, the limiting current for the first wave showed normal diffusion-controlled behavior, i.e., limiting current was proportional to the square root of the height of the mercury reservoir, and had a temperature coefficient of 1.3% per degree.

Influence of Temperature and Head of Mercury on Half-Wave Potential

The temperature-coefficient of the first half-wave potential of carbon tetrachloride was unusually high. In a (2:1) methanol-water mixture, in a (2:1) acetone-water mixture, and in a (1:1) benzene-methanol mixture using potassium iodide, lithium chloride, and tetraalkylammonium halides as supporting electrolytes, the half-wave potential shifted about +3.7 mv/°C. In a (1:4) methanol-water

mixture with lithium chloride and potassium iodide as electrolyte the temperature-coefficient was 3.1 mv/°C. The slightly lower temperature-coefficient in aqueous solutions may indicate a lowering of the activation energy of the electrode process, but the difference is small and may not be significant.

Drop time was another factor of importance for the half-wave potential of carbon tetrachloride. A small shift of the half-wave potential with changing drop time has been predicted by Strehlow and von Stackelberg (13) from a consideration of a modified Ilkovic equation. The shift was predicted, and found to be slightly negative with increasing drop time for thallous and cadmium ions. For carbon tetrachloride, increasing the drop time from 5.5 sec to 16 sec shifted the half-wave potential +0.08 volt in a (2:1) methanol-water mixture which was 0.10*M* in tetramethylammonium bromide. This shift was opposite in sign and of larger magnitude than the shift predicted by Strehlow and von Stackelberg. This behavior of the half-wave potential may account for the discrepancy between the half-wave potential of the present study and that found by Kolthoff and coworkers (10) using the same solution.

An inspection of the waves revealed that the shift of half-wave potential with increasing drop time was due to the fact that the first part of the wave was nearly independent of the head of mercury, whereas the latter part was not (Fig. 8). It was necessary to determine whether this behavior was a general phenomenon, or whether it applied only in this case because the first part of the wave was located on the positive side of the electrocapillary maximum. A run was made with 0.10*M* potassium chloride in a (5:1) methanol-water mixture, where nearly the whole wave was located on the negative side of the electrocapillary maximum. The same relationship between the half-wave potential and the height of the mercury reservoir was found.

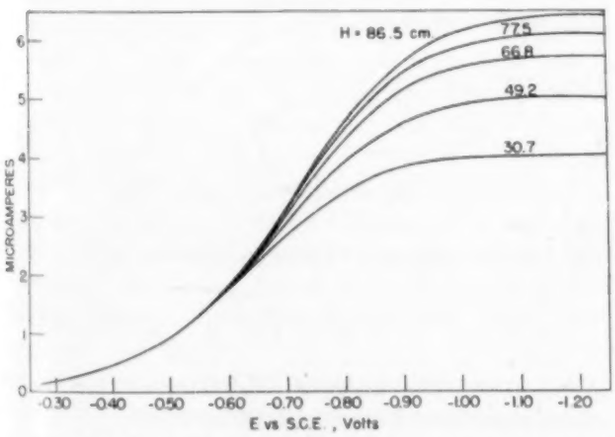

FIG. 8. Effect of the head of mercury on the first wave of carbon tetrachloride in a (2:1) methanol-water mixture containing 0.1*M* tetramethylammonium bromide.

DISCUSSION

Effect of Added Electrolytes on Half-Wave Potential

A large anion effect on the first half-wave potential was observed in predominantly aqueous solutions and a cation effect in predominantly organic solutions. For the second wave only a cation effect was observed. This behavior leads one to suppose that the difference may be explained by the fact that the two waves in aqueous solutions are located on different sides of the electrocapillary maximum of mercury.

A study of Table III reveals that there exists a relationship between the effect of different anions on the half-wave potential and on the electrocapillary curve of mercury. Anions shifted the half-wave potential in the following order: $Cl^- < Br^- < SCN^- < I^-$, which is in the same order as their capillary activity (14). The less capillary active anions OH^-, NO_3^-, and Cl^- gave the same half-wave potential. A relationship between half-wave potential and electrocapillary activity is further substantiated by observing the effect of different iodide concentrations on half-wave potential. Using the shift of the electrocapillary maximum as a measure of the capillary activity, Fig. 9 gives curves for the observed half-wave potential and of the potential of the electrocapillary maximum (14) as a function of the iodide concentration. The shift of the half-wave potential with increasing iodide concentration is of

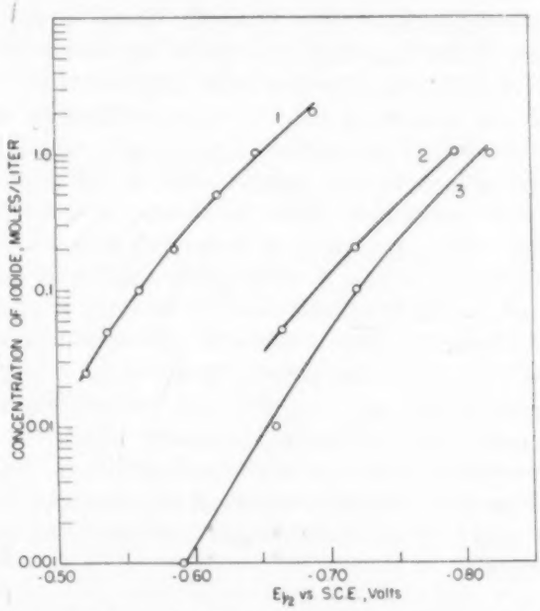

FIG. 9. Effect of iodide concentration on the first half-wave potential of carbon tetrachloride and on the electrocapillary curve of mercury. Curve 1—half-wave potential in (1:4) methanol-water mixtures containing potassium iodide; curve 2—electrocapillary maximum of mercury in (1:4) methanol-water mixtures containing potassium iodide; curve 3—electrocapillary maximum of mercury in water containing sodium iodide (14).

the same magnitude as the shift of the electrocapillary maximum.

This electrocapillary effect on the half-wave potential may be explained by the properties of the electrical double layer which exists between the solution and the mercury drop. Capillary active anions are strongly adsorbed to the mercury surface and form, at potentials more positive than that of the electrocapillary maximum, a sheath of negative ions very close to the mercury drop (the inner Helmholtz plane) (15). Consequently, the electrical potential is much more negative in the inner Helmholtz plane than at the mercury drop, and electrons need more energy to overcome this electrical potential barrier before effecting reduction of the carbon tetrachloride molecule in the inner Helmholtz plane or just outside it. Introduction of more strongly adsorbed anions or higher concentrations of a particular adsorbable anion produces a greater barrier, which in turn requires higher energy of electrons, i.e., a more negative potential to effect reduction. Thus, a change from chloride to iodide of the same concentration results in shifting a half-wave potential on the positive side of the electrocapillary maximum to more negative values.

The fact that waves in the predominantly aqueous solutions are steeper with iodides as electrolyte than with chlorides can be accounted for also. The adsorbed anions are more rapidly desorbed in the case of iodides for a given change toward a more negative potential (16). Thus, the more rapid decrease of this opposing potential in the iodide solutions should favor a steeper polarographic wave.

Similar reasoning can be used to explain the positive shift of the half-wave potential by capillary active cations on the negative side of the electrocapillary maximum. Here, a sheath of adsorbed positive ions produces a potential drop which facilitates reduction. Unfortunately, sufficient data are not available on the capillary activity of tetraalkylammonium salts to allow the effects to be compared. It is, therefore, difficult to say whether or not the shift of the half-wave potential can be explained completely by a capillary activity effect. It is interesting to note that a similar shift of the half-wave potential has been observed by Ashworth (17) in a study of the reduction of benzophenone and fluorenone.

Mechanism of Electrode Reaction

A high temperature coefficient of the half-wave potential is usually associated with an irreversible reaction. The temperature coefficient of the first half-wave potential of carbon tetrachloride, about +3.4 mv/°C, is one of the highest values observed for a polarographic reduction. For comparison, a coefficient of 3 mv/°C was found in the reduction of hydrogen ions (18).

Further indication of the irreversibility of a polarographic reduction can be found in the behavior of the polarographic wave with respect to the height of the mercury reservoir. If the electron-transfer reaction is very slow, the current in the beginning of the wave is limited not by diffusion, but by the drop time-independent electron-transfer reaction rate. This can be shown by making use of the following equation based on the absolute reaction-rate theory for electrode processes (19):

$$\frac{i}{nFA} = [Ox]\cdot k_1\cdot e^{(-\alpha' EnF)/(RT)} - [\mathrm{Red}]\cdot k_2\cdot e^{[(1-\alpha')EnF]/(RT)} \qquad (I)$$

Where A is the area of the electrode; α' is the fraction of the applied potential acting in the direction of reduction; and k_1 and k_2 are the rate constants for the forward and backward electron-transfer reactions in the absence of applied potential. k_1 and k_2 depend on the free energy of activation, ΔF^*, and the standard reduction potential, E^0, of the reaction in the following way:

$$k_i = \frac{kT}{h}\cdot e^{(-\Delta F_i^*)/(RT)} \qquad (II)$$

$$\frac{k_2}{k_1} = e^{-(nFE^0)/(RT)} \qquad (III)$$

where k and h are the Boltzmann and Planck constants, respectively. Concentrations of oxidant and reductant at the interface are given by the Ilkovic equation:

$$i_d - i = \text{const. } nFD_{ox}^{1/2}m^{2/3}t^{1/6}[Ox] \qquad (IV)$$

$$i = \text{const. } nFD_{\mathrm{Red}}^{1/2}m^{2/3}t^{1/6}[\mathrm{Red}] \qquad (V)$$

Introducing these expressions into equation (I) and remembering that the area of the mercury drop is proportional to $m^{2/3}\,t^{2/3}$,

$$i = \frac{i_d}{1 + \frac{D_{ox}^{1/2}}{D_{\mathrm{Red}}^{1/2}}\cdot e^{(E-E^0)nF/(RT)} + \text{const. } \frac{D_{ox}^{1/2}}{k_1\cdot t^{1/2}}\cdot e^{(\alpha' EnF)/(RT)}} \qquad (VI)$$

For present purposes, this is considered as:

$$i = \frac{i_d}{1 + A + B} \qquad (VII)$$

We shall now use this equation to consider the shape of the polarographic wave in three cases:

1. $A \gg B$. When the electron-transfer is rapid, the last exponential in the denominator of equation (VI) can be neglected and the equation becomes

the regular equation for "reversible" polarographic waves where the current is proportional to $m^{2/3}\ t^{1/6}$, and the half-wave potential is essentially independent of drop time.

2. $A \ll B$. This is a highly irreversible reduction, where the electron-transfer process is very slow and, hence, k_1 is small. The first exponential in the denominator of equation (VI) may be neglected so that the current is given by:

$$i = i_d \left[1 + \text{const.} \frac{D_{ox}^{1/2}}{k_1 \cdot t^{1/2}} \cdot e^{(\alpha' EnF)/(RT)} \right]^{-1} \quad \text{(VIII)}$$

At the beginning of the wave, the term 1 may be neglected and the current is independent of the height of the mercury reservoir. At more negative potentials (near the middle of the wave) the term with the exponential is of the same order of magnitude as 1, and the current depends on the drop time, though it is not proportional to $m^{2/3}\ t^{1/6}$. At still more negative values, where the exponential in equation (VIII) may be neglected, limiting current is proportional to $m^{2/3}\ t^{1/6}$ and shows the normal diffusion-controlled behavior.

In this case, the coefficient of the logarithmic term in the equation for the polarographic wave at 30°C is given by:

$$\frac{dE}{d\left(\log \frac{id - i}{i}\right)} = \frac{0.06}{\alpha' n} \quad \text{(IX)}$$

The half-wave potential, more negative than the reversible value in case 1, depends on the drop time in the following way:

$$\frac{dE_{1/2}}{d(\log t^{1/2})} = \frac{0.06}{\alpha' n} \quad \text{(X)}$$

That is, the half-wave potential should be shifted to more positive values with longer drop times, and the magnitude of the shift should be given by the coefficient of the logarithmic term. A plot of the half-wave potential vs. the logarithm of the square root of the drop time should yield a straight line.

3. $A \simeq B$. This case is for an intermediate degree of "irreversibility." The current near the beginning of the wave should be only slightly affected by drop time, whereas the limiting current should show normal diffusion-controlled behavior. The half-wave potential should be found in a region intermediate between the values found in cases 1 and 2, and should depend on the drop time in some complicated manner.

Data for carbon tetrachloride fall into case 2 since the limiting current showed normal diffusion-controlled behavior, whereas the current at the beginning of the wave was independent of drop time. Furthermore, the half-wave potential shifted

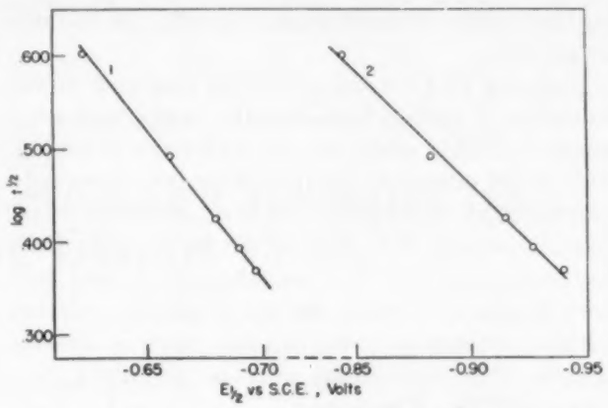

FIG. 10. Half-wave potential of carbon tetrachloride as a function of drop time. Curve 1—0.1M $(CH_3)_4NBr$ in a (2:1) methanol-water mixture; curve 2—0.1M KCl in a (5:1) methanol-water mixture.

to positive values with increasing drop times. Curves in Fig. 10 show that there is a linear relationship between the half-wave potential and the logarithm of the square root of drop time which should be found if the reduction at the beginning of the wave is limited by the rate of the electron-transfer reaction. For a 0.10M potassium chloride—(5:1) methanol-water solution, equation (X) gave 0.15 for $\alpha' n$ and the slope of the polarographic wave gave 0.20. Agreement between the two is reasonably good and indicates that the rate of the electron-transfer reaction is the limiting factor at the beginning of the wave.

The different observed effects of solvents and electrolytes on the polarographic wave of carbon tetrachloride can be represented by the following reaction scheme:

$$CCl_4 + e \rightleftarrows [CCl_3\text{—}Cl]^- \rightleftarrows CCl_3 + Cl^- \quad \text{(XI)}$$

$$CCl_3 + e \rightarrow CCl_3^- \quad \text{(XII)}$$

$$CCl_3^- + H_2O \rightarrow CHCl_3 + OH^- \quad \text{(XIII)}$$

There is a slow addition of one electron to carbon tetrachloride to form an unstable transition state complex of the form $[CCl_3\text{—}Cl]^-$, which at once dissociates to a free radical and a chloride ion. At potentials necessary for this first reduction step, the free radical is immediately reduced further to a negative ion which, in turn, reacts with water to give chloroform. Any factor that contributes to stabilizing the transition state complex, and thereby lowers the activation energy of the first step (k_1 becomes higher), would displace the half-wave potential to more positive values. This is in accord with the observation that reduction is more easily accomplished in water than in organic solvents. Recalling the observed effect of capillary active electrolytes on the half-wave potential, it is obvious that an inactive salt should be used as the support-

ing electrolyte when comparing the effect of solvents on the wave.

Equation (XI), which gives the first step in the reduction of carbon tetrachloride, might indicate a specific chloride effect on the half-wave potential. This is not observed. The reason for this seemingly contradictory behavior is that the chloride effect enters equation (VI) only in the factor before the last exponential in the denominator. It has just been shown that when the polarographic reaction is highly irreversible owing to a slow electron-transfer process, this exponential may be neglected, i.e., equation (VIII) is operating.

Maxima on the Polarographic Wave

Behavior of the maximum for carbon tetrachloride is difficult to reconcile with currently accepted theories of maximum formation. The observation that current-time curves for individual drops in the region of maximum formation had irregular shapes and went through one or two maxima (Fig. 6) might indicate adsorption phenomena, where each maximum on the current-time curve corresponds to a different adsorption process. However, the effect of temperature makes an explanation based upon adsorption less likely. The electrokinetic theory set forth by Antweiler (20), where a difference in potential at different parts of the drop causes streaming of the solution around the drop, might help to explain the phenomena. One would expect capacity currents to be smaller than observed currents. It is possible that a new reaction mechanism favored by higher temperatures occurs in the predominantly aqueous solutions.[5]

Acknowledgment

Discussions with Mr. Hugh Keily as well as criticism of the manuscript by Professor David C. Grahame and Professor Philip J. Elving are gratefully acknowledged.

One of the authors (J.J.L.) is indebted to Royal Norwegian Council for Scientific and Industrial Research for a fellowship; the other (L.B.R.) wishes to thank the Atomic Energy Commission for partial support.

Any discussion of this paper will appear in a Discussion Section to be published in the December 1954 issue of the JOURNAL.

[5] After the present manuscript had been submitted for publication, the authors found an abstract of the work of Frumkin and Florianovitch (21) in which the shift toward positive potentials of the reduction waves for nitrates, bromates, and iodates by the addition of cations was explained by a theory very similar to the one proposed here for carbon tetrachloride. Likewise, a paper by Kivalo, Oldham, and Laitinen (22) has just been published in which the hexaaquonickel (II) ion was employed to show experimentally dependence of half-wave potential on drop time and of the current on head of mercury in much the same way that carbon tetrachloride was used in the present study.

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Current Affairs

FTC Cites Evis Manufacturing Company on Advertising Claims

This item will be of particular interest to members of the Corrosion Division, as well as to the members of the Society in general.

Advertising claims that the Evis Water Conditioner "makes hard water feel, taste, and act softer," giving it a "silky-smooth quality" for hair, bath, dishes, laundry, and car wash, without the use of chemicals, are "false, misleading and deceptive" according to a Federal Trade Commission complaint.

The complaint cites Evis Manufacturing Company, San Francisco, together with Joseph T. Voorheis, as president, and Arthur N. Wells, as vice president.

According to the complaint, the product is a metal device which "has the appearance of an oversized pipe coupling with an interior cross post integrally cast in place." It is intended to be fitted into water systems for the purpose of beneficially treating and conditioning water.

The complaint lists as false and misleading the company's representations that the product:

Is made of a specially processed cast metal and has a catalytic effect on water passing through it which changes its physical behavior in many beneficial ways.

Solves hard water problems, causing "hard" water to become soft.

Removes and reduces unpleasant odors and flavors in water, making it taste better, and improves the taste of coffee and other foods.

Requires the use of less soap and reduces the cost of heating water.

Eliminates or reduces the harshness of water to the hands and causes dishes and glassware to dry without leaving water stains.

Removes grease from drains and prevents and removes scale from boilers, water heaters, pipes, shower nozzles, and other parts of a water system.

Prevents, reduces, and eliminates scum, rust stains, and corrosion and retards the pitting of metal.

Improves the action of chemicals used for water softening purposes

Leaches out alkali and salts in soil, improves the growth and production of various agricultural and orchard products and plants, and improves the texture and structure of soil.

Reduces the amount of water required for agricultural irrigation.

The respondents were granted 20 days to answer the complaint. Hearings in the case began April 8 in San Francisco.

NOTE: Following the above complaint was a formal "Notice" to the Evis Manufacturing Company, from the Federal Trade Commission, notifying the Evis Company of the hearing set for April 8, 1954 at San Francisco, California.

The Evis Company was given until April 8 to "show cause why an order should not be entered requiring you to cease and desist from the violations of law charged in this complaint." This means, of course, that the Evis Company can either admit or deny the FTC charges.

Special Corrosion Program at M.I.T.

A special one-week summer program in Corrosion, to summarize the fundamental and recent advances in this field, will be given at the Massachusetts Institute of Technology June 21–25.

Dr. Herbert H. Uhlig, Professor of Metallurgy, will be in charge of the summer program. Special lecturers, in addition to Professor Uhlig, will include Milton Stern, Research Associate in Metallurgy at M.I.T.; W. Z. Friend and F. L. LaQue of the International Nickel Company, Inc.; L. P. Sudrabin of the Electro Rust-Proofing Corporation; R. M. Burns of the Bell Telephone Laboratories, Inc.; and Professor Norman Hackerman of the Department of Chemistry, University of Texas.

The program, according to Professor Uhlig, will include a presentation of fundamentals of corrosion reaction and control, followed by consideration and discussion of proper selection of corrosion resistant materials, chemical treatment of the environments, theory and practice of cathodic protection, selection of coatings and alloys economically feasible for reducing corrosion losses, and corrosion testing. Lecture table demonstrations will be shown and ample opportunity will be provided for questions and informal discussions.

In addition, registrants will visit the William F. Clapp Laboratories at Duxbury, Massachusetts, on Saturday, June 26, where Mr. A. P. Richards, president of the laboratories, will describe various research projects in marine fouling.

Tuition for the one-week special summer program in Corrosion will be $100. Further information and application blanks are available from the Summer Session Office, Room 7-103, M.I.T., Cambridge 39, Mass.

Programs in Instrumental Chemical Analysis

Two special summer programs in Instrumental Chemical Analysis, to enable chemists in industry and government laboratories to study the application of new instrumental techniques and methods in the field of applied

analytical chemistry, will be given during the 1954 Summer Session at the Massachusetts Institute of Technology.

The first program, from August 16–20, will be devoted to electrical methods of instrumental chemical analysis; the second, from August 23–27, will deal with optical methods of instrumental chemical analysis.

Both programs will be under the direction of Dr. David N. Hume and Dr. Lockhart B. Rogers, Associate Professors of Chemistry at M.I.T., who are in charge of the Institute's Instrumental Analysis Laboratory.

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Mr. McKay outlined briefly the early history of work pertaining to the role of oxygen in galvanic cells. The dearth of such work for some 120 years after the first observations in the early 1800's now seems remarkable in the light of the significance which is attached at present to such studies for a complete understanding of corrosion. He also pointed out that only about 30 years ago the electrolytic theory of corrosion was based entirely on the existence of dissimilar electrodes and that it has been only since that time that the importance of variation in concentration of surrounding electrolyte has become recognized.

Mr. McKay then described some experimental work which he has been conducting recently on oxygen concentration cells comprising steel electrodes immersed in salt water with oxygen supplied to one of the electrodes which then becomes cathodic while the other electrode dissolves. The quantitative data which he has obtained under a variety of conditions should lead to a

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Philadelphia Section

Robert J. McKay, President of The Electrochemical Society, was the speaker at the March 10 meeting of the Philadelphia Section. After about 40 members and guests had met and dined with the speaker at the Lenape Club, Mr. McKay spoke on the subject of oxygen concentration cells in corrosion.

Mr. McKay outlined briefly the early history of work pertaining to the role of oxygen in galvanic cells. The dearth of such work for some 120 years after the first observations in the early 1800's now seems remarkable in the light of the significance which is attached at present to such studies for a complete understanding of corrosion. He also pointed out that only about 30 years ago the electrolytic theory of corrosion was based entirely on the existence of dissimilar electrodes and that it has been only since that time that the importance of variation in concentration of surrounding electrolyte has become recognized.

Mr. McKay then described some experimental work which he has been conducting recently on oxygen concentration cells comprising steel electrodes immersed in salt water with oxygen supplied to one of the electrodes which then becomes cathodic while the other electrode dissolves. The quantitative data which he has obtained under a variety of conditions should lead to a

fuller understanding of many important problems of corrosion. The numerous questions raised at the close of Mr. McKay's address attested to the keen interest in this subject.

GEORGE BODAMER, *Secretary*

Washington-Baltimore Section

Mr. Sigmund Schuldiner, of the Naval Research Laboratory, discussed "Hydrogen Overvoltage on Bright Platinum" at the February 18 meeting of the Washington-Baltimore Section. Mr. Schuldiner defined hydrogen overvoltage and gave a description of the various components which comprise an overvoltage measurement. A thermodynamic-kinetic derivation of the Tafel equation was given, assuming the reversible discharge of hydronium ions followed by a rate-controlling combination reaction.

The experimental techniques used were described and results of hydrogen overvoltage measurements on bright platinum over the *p*H range 0.5–12.1 were given. Effects of added sodium and ammonium ions and *p*H were shown and relative rates of the over-all hydrogen producing reactions at low current densities were determined. A theoretical discussion of the mechanism of hydrogen overvoltage in these solutions followed, and the relationship between the *p*H effect on overvoltage and the buffer capacity of the solutions was shown.

FIELDING OGBURN, *Secretary*

MEETINGS OF OTHER ORGANIZATIONS

L'ALUMINIUM FRANCAIS and LA SOCIETE CHIMIQUE DE FRANCE, Scientific Congress and Exhibition, Paris, June 14–19, celebrating centenary of the first production of industrial aluminum in France by Henry Sainte-Claire Deville. Program and other relevant information available from the Secretary, L'Aluminium Francais, 23 Rue Balzac, Paris (8e), France.

INSTRUMENT SOCIETY OF AMERICA, third annual Analytical Instrument Clinic to be held in conjunction with the First International Instrument Congress and Exposition, Philadelphia, Sept. 13–15. Advance registration required. For registration forms and further information write Dr. Axel H. Peterson, Mellon Institute, 4400 Fifth Ave., Pittsburgh 13, Pa.

FIRST INTERNATIONAL INSTRUMENT CONGRESS AND EXPOSITION, Philadelphia, Sept. 13–24.

THIRD SALON DE LA CHIMIE ET DES MATIÈRES PLASTIQUES, Paris, Dec. 3–12.

NEW MEMBERS

In March 1954 the following were elected to membership in The Electrochemical Society:

Active Members

CHARLES E. BATES, General Motors Corp., West Willard Street, Muncie, Indiana (Battery)

MICHAEL D. BENEDICT, The Gillette Co., Research Lab., Boston, Mass. (Corrosion)

PAUL F. BENTE, JR., E. I. du Pont de Nemours and Co., Niagara Falls, N. Y. (Electrodeposition)

BUSHNELL BEST, Great Lakes Carbon Corp., Niagara Falls, N. Y. (Industrial Electrolytic)

ROBERT COX, N. V. Koninklijke Nederlandsche Zoutindustrie, Boortorenweg 27, Hengelo (O), Netherlands (Battery, Corrosion, Electrodeposition, Electro-Organic, Electrothermic, Industrial Electrolytic, Theoretical Electrochemistry)

EUGENE D. GRYGLAS, Cinch Mfg. Corp., mail add: 2855 N. Linder Ave., Chicago, Ill. (Electrodeposition)

RICHARD J. HALSTED, Glidden Co. Chemical Pigments Div., mail add: 213 Dumbarton Road, Baltimore, Md. (Industrial Electrolytic)

DONALD E. HASBROUCK, U. S. Rubber Co., 1230 Ave. of the Americas, New York, N. Y. (Battery, Electric Insulation)

RICHARD P. HUNNICUTT, General Motors Corp., mail add: 627 Woodlawn Ave., Royal Oak, Mich. (Electrodeposition)

WILLIAM M. KING, Clevite Brush Development Co., mail add: 1827 E. 291 St., Wickliffe, Ohio (Electrodeposition) Formerly Associate Member

ERIC A. OLLARD, British Non-Ferrous Metals Research Association, Euston Street, London N. W. 1, England (Electrodeposition, Theoretical Electrochemistry) Faraday Transfer

HAROLD DEBLOIS RICE, Gar Precision Parts Inc., 36 Ludlow St., Stamford, Conn. (Corrosion, Electrodeposition, Electronics, Industrial Electrolytic)

BILL F. ROTHSCHILD, Federal Mogul Corp., 2355 Stadium Blvd., Ann Arbor, Mich. (Corrosion, Electrodeposition)

CLEMENT G. STEIDL, Oxford Paper Co., mail add: 17 Porter Ave., Rumford, Maine (Industrial Electrolytic)

WILLIAM F. SWIGER, Lavino Chemical Co., mail add: 16 2nd St. N.E., Carrollton, Ohio (Electrodeposition, Industrial Electrolytic)

THOMAS ZWADZKI, Firestone Plastics Co., Pottstown, Pa. (Electric Insulation)

Active Reinstatement

FREDERICK H. PERFECT, Reading Chemicals, mail add: 1556 Penn Ave., Wyomissing, Pa. (Electrothermic)

Associate Members

ROGER J. LABRIE, National Bureau of Standards, Washington, D. C. (Electrodeposition)

WAYNE G. POLZIN, Diversey Corp., 1820 Roscoe St., Chicago, Ill. (Electrodeposition)

JOSTEIN J. VADLA, National Carbon Co., mail add: 228 4th St., Niagara Falls, N. Y. (Industrial Electrolytic)

Student Associate Member

HERMAN WISSENBERG, University of Michigan, mail add: 911 Hutchins St., Ann Arbor, Mich.

PERSONALS

H. W. SCHMIDT, Dow Chemical Company, Midland, Mich., and C. P. LARRABEE, U. S. Steel Corporation, Vandergrift, Pa., have been named members of the Technical Practices Committee of the National Association of Corrosion Engineers. This committee will be the policy making group for the association's technical activities.

CARLTON M. DEAN, Monsanto Chemical Company, St. Louis, Mo., has been made director of engineering sales of the company's newly created Research and Engineering Division, formed as part of an over-all move to provide more effectively for anticipated growth. Mr. Dean was manager of engineering sales in the Organic Chemical Division.

IDA M. PATTERSON, chemist at the Naval Research Laboratory, Washington, D. C., recently transferred from the Chemistry Division, Electrochemistry Branch, to the Metallurgy Division, Corrosion Branch.

WILLIAM M. RAYNOR has been assigned to assist the vice-president in charge of sales at Foote Mineral Company, Philadelphia, Pa. Mr. Raynor will continue as manager of Special Products Sales of the company in addition to his new responsibilities.

LESTER E. LIGHTON, vice-president in charge of engineering at the Electric Storage Battery Company, Philadelphia, Pa., was recently granted a patent by the U. S. Patent Office for an improvement in storage battery cells. Mr. Lighton now has six patents to his credit.

JOHN E. BARKLEY, one of the country's leading research managers in the physical chemical field, has become manager of physics and chemistry research for the Mechanical Division of General Mills, Inc., Minneapolis, Minn. He was formerly head of physical-chemistry research at Armour Research Foundation, Chicago, Ill.

HERBERT P. DENGLER has joined the staff of the Esso Engineering Department, Standard Oil Development Company, Linden, N. J.

ELMER A. THURBER, a pioneer member of the technical staff of Bell Telephone Laboratories, has recently been appointed a representative of the Chemical Physics Department at the Allentown, Pa., plant of Western Electric Company. In his new capacity he is responsible for chemical engineering services requisite to advanced development and pilot production of electronic devices.

BOOK REVIEWS

ELECTROCHEMICAL CONSTANTS, National Bureau of Standards Circular 524. For sale by Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. 310 + iv pages, $2.00.

This monograph reports the proceedings of the National Bureau of Standards Semicentennial Symposium on Electrochemical Constants held at the NBS on September 19–21, 1951. Taking part in the symposium were a distinguished group of electrochemists, many being leaders in their respective fields. The title of this book is somewhat misleading since it contains many excellent reviews on modern electrochemical theory as well as discussions on the present status of electrochemical constants.

The standardization of specific electrochemical constants are considered in papers on: (*a*) the faraday constant, (*b*) conductance, (*c*) moving boundary measurements, (*d*) diffusion coefficients, (*e*) thermal diffusion, (*f*) the unit of emf, (*g*) the *p*H scale, (*h*) activity coefficients, (*i*) electrical double layers, and (*j*) polarographic constants. The problems of inclusions in the silver of the silver coulombmeter and with septa in standard voltage cells are the subject of two articles.

Included also are papers on electrochemical kinetics dealing with: reaction rates in dilute electrolyte solutions; the mechanism of overvoltage; parameters of electrode kinetics; and electrokinetics of capillary systems and colloidial solutions. Other topics are: absolute half-cell potentials; iodide-iodine solutions with the emf centrifuge; thermoelectric and thermomagnetic effects; and use of potential diagrams in interpreting inorganic chemistry. A few of the papers appear only in abstract form. The discussion which followed the presentation of each paper was recorded and is included in the monograph.

The book is well bound and nicely printed on a good grade of paper. It is a worthwhile addition to an electrochemist's library.

D. R. TURNER

THE COMPOSITION AND ASSAYING OF MINERALS by John S. Remington and Wilfrid Francis. Published by the Philosophical Library, Inc., New York, 1953. 127 pages, $5.50.

Students and workers in the mineralogical sciences will find this text book a convenient working reference to the techniques of identification and analysis of the common rock and ore forming minerals. Some 100 of the 127 pages of the text are given over to the descriptive mineralogy of ore minerals and the specific qualitative and quantitative techniques of identification. Detailed procedures and typical analyses are given for the assay of gold-silver, zinc, lead, and manganese ores. In the remaining text is made a brief presentation of the rapid and preliminary qualitative tests of physical and chemical mineralogy, and of the descriptive mineralogy of the more common rock forming silicates. (An error was noted on page 115. In the determination of SiO_2 by volatilization weight loss, HF should be substituted for HCl.) The text is concluded with a useful 9-page appendix of chemical and mathematical data.

Although it is not intended to be an exhaustive treatment, the book suffers from the lack of an index and reference citations. In particular, lack of reference to the rapid and accurate Bureau of Standards colorimetric methods of silicate rock analysis is a serious omission. The need for standardization between the English and the American mineralogical nomenclatures and formulations is also evident. The authors' expression of mineral compositions in terms of oxides and sulfides gives the undesired impression of a double salt. More conventional structural formulas are to be preferred.

As a supplementary working reference and handy guide, this book should prove useful to those working in the earth sciences and related fields.

STEWARD S. FLASCHEN

LETTER TO THE EDITOR

Journal Advertising

Dear Sir:

This letter carries my reasons for being disappointed on seeing advertising carried within the Technical Section of the March issue of the JOURNAL. Considering the fine job done by the present editorial staff and the increasingly higher standards achieved by papers currently published, it is painful to level criticism at a job otherwise magnificently done. But to let the present violation of the Technical Section pass by unnoticed, and thereby assent to it by silence, would be to fail my responsibility as a member of the Society and as a past member of the editorial staff.

High standing is achieved by a journal such as ours through the publication of high-quality scientific papers. There is at no time any suspicion of compromise between the allowable reported facts and the claims of the advertisers. The chips fall where they may, whether or not those who pay for or solicit ads are offended or pleased by the published papers. In other words, published papers obviously and invariably dominate the publication, and scientific considerations alone determine the policy governing papers accepted or rejected for publication. Advertisements, on this basis, are placed where they do not intrude into the main body of the publication, and, in order to remove even faint suspicions, advertisements are never al-

lowed to scramble the Technical Section any more than they are allowed as subject matter of a submitted paper.

The above is the policy I believe we should follow. Our journal deserves every reasonable chance of growing into an acceptable scientific publication, a trend to which many of our members are contributing much of their personal time and effort without compensation. This trend can only be maintained by keeping publication standards high, and relegating all advertising, without exception, to a secondary role in the JOURNAL makeup. Any other policy, I am convinced, marks a step backward.

Ideally, the JOURNAL should accept only dignified (not lurid, tabloid-type) advertising, each page of which is referred to the beginning or end of the JOURNAL. If the Society at any time is in need of income beyond revenues of this kind, we had better turn to increased sustaining memberships, or increased dues, or to a system of charging authors per page for papers published, rather than place on sale our standing in scientific circles. Only in this way do I believe that we discharge our primary responsibility to the authors and readers of the technical and scientific papers we publish, and only in this way can the Society hope to achieve financial security based on an increasing membership and an expanding dependable support from industry.

H. H. UHLIG
Massachusetts Institute of Technology
Department of Metallurgy
Cambridge, Mass.

RECENT PATENTS

Selected by Fred. W. Dodson, Chairman of the Patent Committee, from the Official Gazette.

February 2, 1954

Gilbert, Jr., P. T. and Arthur, E. P., 2,668,143, Glass Electrode

Kröger, F. A., and Boomgaard, J. van den, 2,668,148, Thallium Activated Calcium Phosphate Phosphor Containing Aluminum

Foyn, K., 2,668,183, Electrode Suspension Mechanism and Method of Operation

Taylor, C. F., Briggs, W. E., and Weary, J. F., 2,668,184, Multiple Photocell Structure

Castlen, R. C., 2,668,185, Visible Liquid Level Indicating Nonspill Vent Mechanisms

Ouweltjes, J. L., 2,668,252, Electric Lamp

February 9, 1954

Wernlund, C. J., 2,668,795, White Brass Plating

Ekstein, C., 2,668,867, Photocell Construction

Nelson, C. G., 2,668,868, Flat Dry Cell Battery Pack

Bowden, J. J., Reissue 23,778, Method of Fluidizing Slag In the Manufacture of Steel by Open Hearth and Electric Furnace Processes

February 16, 1954

Larsen, E. I., Doty, A. S., and Williams, D. A., 2,669,512, Electric Contact Material and Method of Making the Same

Dooley, W. P., 2,669,542, Electrolysis of Sodium Sulfate

Larsen, B. M., 2,669 593, Aspirator Thermocouple Mounting for Measuring the Temperature of Hot Gases

André, H. G., 2,669,594, Electrical Accumulator

Gary, W. W., Jr., 2,669,595, Alkaline Battery

Nelson, F. H., 2,669,596, Reserve Battery Enclosure

Ruben, S., 2,669,597, Electric Current Producing Cell with Tin Anode

Marko, A., and Kordesch, K., 2,669,598, Process for Manufacturing Porous Carbon Electrodes

Clark, E., 2,669,599, Storage Battery Plate Separator

Geiselman, R. A., and Biggs, G. C., 2,669,673, Arc Furnace Control System

February 23, 1954

Hecht, B. P., and Koury, F., 2,669,767, Selenium Rectifier

Bungay, G. W., 2,670,326, Producing Curved Electrotypes

Rader, C. M., 2,670,327, Electrolytic Liquid Treating Device

West, O. A., 2,670,394, Shield Means for Pilot Burners and Thermocouple of Gaseous Fuel Burners

A Cue for You on Potassium Silicates

- Can these chemical properties help you?

Product	K_2O	SiO_2	% Ratio	Baumé
Kasil #1*	7.80%	19.5%	1:2.50	28.0°
Kasil #6	12.60%	26.8%	1:2.10	40.75°
Kasil #22*	8.60%	18.9%	1:2.20	28.6°
Kasil #44	7.80%	19.5%	1:2.50	28.0°

- Here are some uses for these potassium silicates

Use	Product	Advantages
Cathode ray tubes	Kasil #1 Kasil #22	Uniform settling & binding of phosphors
Welding Rod Coatings	Kasil #6 Kasil #44	Good bond & fluxing action
Liquid & Paste Soaps	Kasil #1 Kasil #6	Increased sudsing and suspending powers
Paints	Kasil #1	Non-blooming film
Asbestos Cement Board	Kasil #44	Non-blooming film
Detergents	Kasil #1 Kasil #6	Improved cleaning
Catalyst	Kasil #1	Free of sodium salts

We're happy to discuss your use for potassium silicate and to send you test samples of the proper Kasil for it.

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MANUFACTURERS OF SOLUBLE SILICATES
1156 Public Ledger Bldg.
Philadelphia 6, Pa.

Audubert, R., and Calmar, C., 2,670,395, Method for the Preparation of Depolarizers for Electric Cells

Field, B. R., 2,670,396, Venting and Pressure Release Arrangement of Electric Accumulators

LITERATURE FROM INDUSTRY

"Electroplating with Rhodium." Illustrated booklet lists data and directions for electroplating with rhodium. Includes information on physical and electrical properties, corrosion resistance, and thickness specification of rhodium, and the cost of plating. General instructions given on preparation of work, electrocleaning, underplating, plating baths and their maintenance, stripping. Some practical hints for the plater are also discussed. Baker & Co., Inc. P-202

D-C Electrical Equipment. A complete line of d-c electrical equipment for use in electroplating processes is pictured and described in a new 4-page, 2-color bulletin. The line includes d-c generators, rectifiers, PR controllers, tank rheostats, and special panels. An unusual feature of the bulletin is that both generators and rectifiers are covered, and their respective characteristics listed side by side. Information is given for the generators on standard voltage ratings, special construction of the brushes and holders, design of shunts, type of sleeve bearings, and construction of the generator ring. Photos are included for all equipment covered. Hanson-Van Winkle-Munning Co. P-203

Two Accurate Ways to Measure High Resistance are discussed in a recent issue of Keithley Engineering Notes. The first method, involving a Keithley vacuum tube electrometer and shunt, permits measurements to 124,000,000 megohms full scale, at an absolute accuracy of within 5%. The second method employs an electrometer and low-leakage capacitor, and achieves similarly high sensitivity. Both methods permit the measurement of resistances far byond the reach of bridges, megohmmeters, and wall galvanometers. Keithley Instruments. P-204

Sodium Sesquisilicate. Publication has been announced of a booklet which describes in detail the properties and uses of Metso 99, sodium sesquisilicate. It deals with the evaluations of sodium sesquisilicate with respect to the basic detergent properties of wetting, emulsification, dirt suspension, and prevention of redeposition. Also included is a demonstration of the product's ability to protect sensitive metals such as magnesium, copper, zinc, and brass when used alone or in conjunction with synthetics and polyphosphates. Popular detergent uses and general directions are tabulated by industry. A copy of the booklet will be sent to anyone requesting it on company stationery. Philadelphia Quartz Co. P-205

Laboratory Ovens. The subject of a new 8-page bulletin (FS-230) is the laboratory oven, an apparatus equally important to research, testing, quality control, clinical, and educational laboratories. Listed and described is the complete line of Fisher "isotemp" ovens. A summary is given of the basic studies in heat transfer that led Fisher engineers to turn the conventional "box" heated by warmed air into a uniform-temperature apparatus heated by its own aluminum walls. Fisher Scientific Co. P-206

Printed Circuit Sockets. Currently off the press is a descriptive sheet on MYCALEX (Registered trade mark of the Mycalex Corporation of America) glass-bonded mica printed circuit sockets, giving specifications for various grades of MYCALEX. Mycalex Corp. of America. P-207

NEW PRODUCTS

Voltage Dividers. Two new resistive voltage dividers, Models 2006 and 2007, have been announced. Have maximum inputs of 2000 and 20,000 volts, respectively, and input impedances of 10^{12} ohms. These voltage dividers make available a new type of high-impedance d-c kilovoltmeter. Features include unusual portability, polarity sensitivity, very short time constant, and wide selection of voltage ranges. Typical applica-

ELECTROCHEMIST

Major electrochemical producer located in deep south needs man to assume responsibility for experimental phase of development program on fused salt electrolysis. Must have several years' experience in laboratory or plant development of fused salt or other electrolytic cells. This position requires more than average drive, imagination, and creative ability. At least B.S. degree in chemistry, chemical engineering, or related field is required. Interested persons are requested to submit full details of their qualifications to

Box A-254.

tions for the new equipment are in measuring voltages on cathode ray tubes, TV picture tubes, x-ray and radiation equipment, leakage of high-voltage insulators, and testing the voltage breakdown of cables. Keithley Instruments. N-69

COLD CATHODE ELECTRONIC COUNTER. A precision, direct readout cold cathode electronic counter (Model RC) designed to operate at speeds up to 10,000 counts per minute and having a total counting capacity of 9,999,999 is now available. It operates at an accuracy precision of ±0 while maintaining a low power consumption. Features include longer life and accurate dependability, complete independence from line voltage variations and fluctuations, easy readability, efficient and instantaneous operation. Haledy Electronics Co. N-70

ELECTRONIC TEMPERATURE CONTROLLER. High sensitivity, long term stability, reliability, and low cost are featured in a new two-zone electronic temperature controller. The unit is designed for a wide range of industrial applications in all industry where accurate temperature control is required, including applications in petrochemical processing, the plastic molding and extruding field, and explosives manufacturing. Also suitable for use in laboratory work. Standard ranges are zero to 100, 300, or 500 degrees Fahrenheit and Centigrade. Sensitivity is 0.1°F on all ranges. Only two vacuum tubes are employed and the unit is encased in a strong cast aluminum housing. Robertshaw-Fulton Controls Co. N-71

GLENNITE SUBMINIATURE RESISTORS. In response to the demand for very small, low power components, a unique line of Glennite subminiature resistors has been developed. Especially suitable for transistorized assemblies, the resistors can be used individually in multiples, in packaged R-C circuits, or incorporated into printed networks. Made of a special material deposited on a thin ceramic base. Dimensions and electrode and lead arrangement are flexible enough to accommodate any special requirements. The Glenco Corp. N-72

REDOX-O-TROL, a new apparatus, provides precise, automatic control of electrochemical reactions by controlling electrode potentials and has sufficient output for preparing selective reduction and oxidation products in substantial quantities. Controls electrode potentials within 100 mv. Has been used successfully in the preparation of pinacols of *p*-aminoacetophenone and *p*-aminopropiophenone. Useful also for electrolytic separation and determination of metals and for precise control of numerous chemical reactions. Outputs delivered range from 0.1 to 7 amperes at voltages from 1 to 27. American Instrument Co., Inc. N-73

HIGH TEMPERATURE GERMANIUM DIODES. A "Red Dot" series of germanium diodes for high temperature applications is now being produced. Especially developed for equipment operating at a high ambient temperature, they have far superior forward and reverse characteristics than conventional diodes at high operating temperatures. May be identified by the special "Red Dot" marking on the glass housing. Each unit so well sealed that exposure to 95 plus % relative humidity for 500 hr at temperatures from 0°–85°C will not appreciably change back resistance or cause appearance of hysteresis. Designed for either clip-in or solder-in application. International Rectifier Corp. N-74

INTEGRATING INSTRUMENTS. Two new integrating instruments, one current-integrating and the other current-squared integrating, have been announced. The instruments are designed for the solution of quality control problems encountered by the manufacturers of yarn, wire, strip metals, photo film, rope, plastics, and similar products in continuous moving processes. Permit rapid determination of the average thickness and standard deviation of tested samples; contain no control springs and have a special mechanism that provides a high degree of damping; afford unusually accurate readings. General Electric Co. N-75

ULTRASONIC-POWER GENERATOR. The "Sonogen" Model 500 ultrasonic-power generator is designed primarily for accelerating the cleaning and degreasing of small parts and metal objects such as strip, wire, and tubing, as well as complex components. It functions by activation of the cleaning solvent in which is immersed the low-voltage focused ceramic transducer. Radio-frequency output of the generator is 500 watts continuously at 450,000 cycles per second. In addition to cleaning, the Sonogen is an economical source of ultrasonic power for many other laboratory and production uses involving liquids, such as emulsification, dispersion, and the acceleration of chemical reactions. Branson Instruments, Inc. N-76

To receive further information on any New Product or Literature from Industry listed above, send inquiry, with key number, to JOURNAL of The Electrochemical Society, 216 West 102nd Street, New York 25, N. Y.

Please print your name and address plainly.

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EMPLOYMENT SITUATION

Please address replies to box shown, % The Electrochemical Society, Inc., 216 W. 102nd St., New York 25, N. Y.

Position Wanted

ELECTROMETALLURGIST. B.S., M.S., and Ph.D. degrees in metallurgy. Permanent resident alien. Eight years in nonferrous and corrosion research. Knowledge of corrosion, hydro- and electrometallurgy, radiography, x-ray diffraction, spectro-analysis, and heat treatment. Desires position in research, production, or plant control with opportunity for experience and advancement. Location immaterial. *Reply to Box 355.*

The Electrochemical Society

INSTRUCTIONS TO AUTHORS OF PAPERS

Address all correspondence to the Editor, JOURNAL OF THE ELECTROCHEMICAL SOCIETY, 216 W. 102nd St., New York 25, N. Y.

FORM

Manuscripts submitted for publication should be in triplicate to expedite review. They should be typewritten, double-spaced, with 2½–4 cm (1–1½ in.) margins.

Title should be brief, followed by the author's name and his business or university connection.

Abstract of about 100 words should state the scope of the paper and give a brief summary of results.

ILLUSTRATIONS

Drawings will be reduced to column width, 8 cm (3⅛ in.), and after reduction should have lettering at least 0.15 cm (1/16 in.) high. Original drawings in India ink on tracing cloth or white paper are preferred. Curves may be drawn on coordinate paper only if the paper is ruled in blue. All lettering must be of lettering-guide quality. See sample drawing on reverse page.

Photographs must be glossy prints and mounted flat.

Captions for all figures must be included on a separate sheet. Captions and figure numbers should not appear in the body of the figure.

General—Figures should be used only when necessary. Omit drawings or photographs of familiar equipment. Figures from other publications are to be used only when the publication is not readily available, and should always be accompanied with written permission for reprinting.

REFERENCES

Literature and patent references should be listed at the end of the paper on a separate sheet, in the order in which they are cited. They should be given in the style adopted by *Chemical Abstracts*. For example:

R. Freas, *Trans. Electrochem. Soc.*, **40,** 109 (1921).

H. T. S. Britton, "Hydrogen Ions," Vol. **1,** p. 309, D. Van Nostrand Co., New York (1943).

H. F. Weiss (To Wood Conversion Co.), U. S. Pat. 1,695,445, Dec. 18, 1928.

UNITS OF MEASUREMENT

Metric units should be used throughout but, where desirable, English units may be given in parentheses.

Corrosion rates in the metric system should preferably be expressed as milligrams per square decimeter per day (mdd), and in the English system as inches penetration per year (ipy).

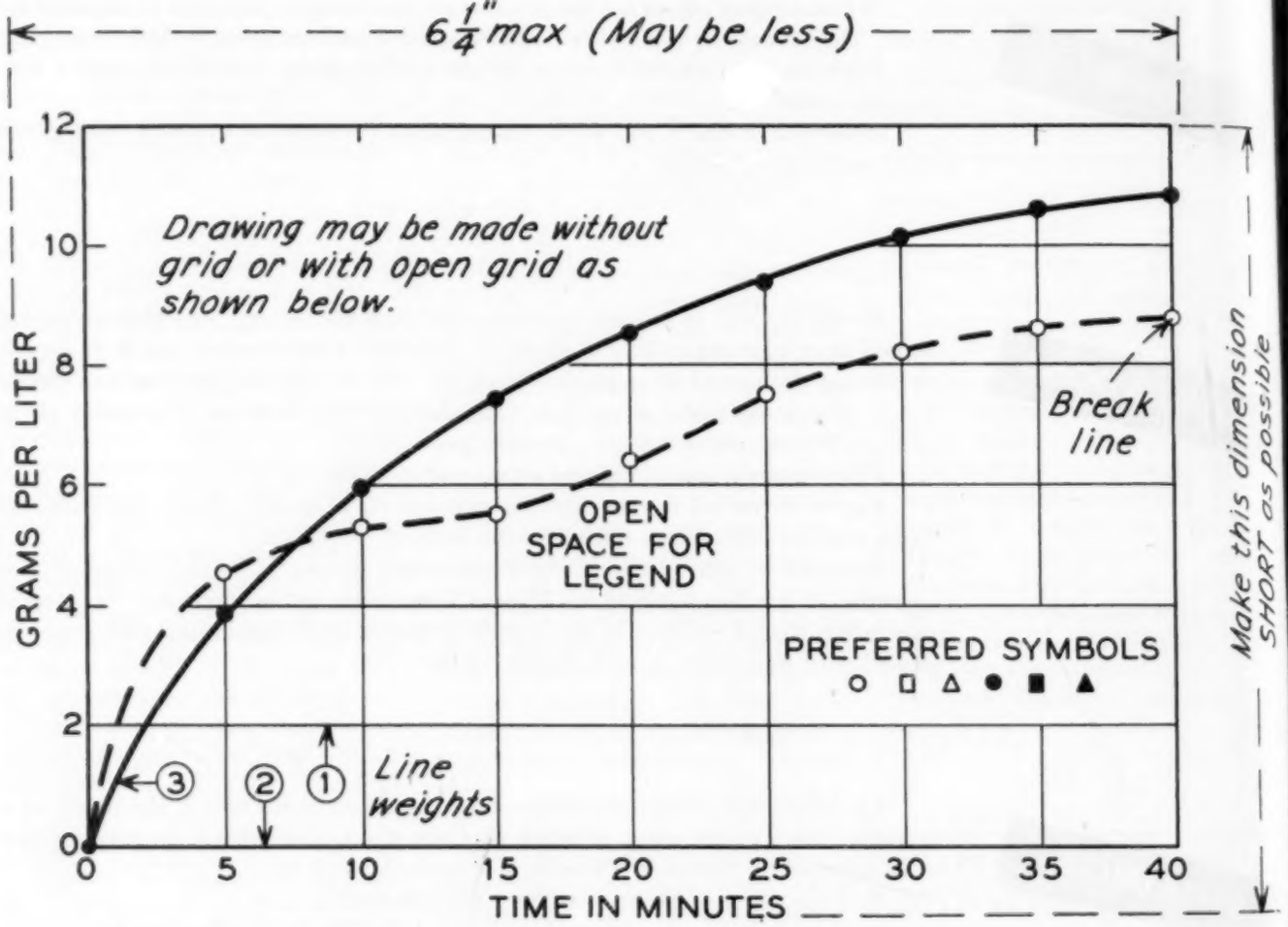
As regards algebraic signs of potentials, the standard electrode potential for $Zn \rightarrow Zn^{++} + 2e$ is negative; for $Cu \rightarrow Cu^{++} + 2e$, positive.

Abbreviations should conform with the American Standards Association's list of "Abbreviations for Scientific and Engineering Terms."

GENERAL

Authors should be as brief as is consistent with clarity, and must omit all material which can be regarded as familiar to specialists in the particular field.

The use of proprietary names, trade-marks, and trade names should be avoided if possible. If used, these should be capitalized so that the owner's legal rights are not jeopardized.



Remarks: Line weight ② is used for borders and zero lines. When several curves are shown, each may be numbered and described in the caption. Lettering is approx. 1/8".

SAMPLE CURVE DRAWING FOR REDUCTION TO $\frac{1}{2}$ SIZE

Feature Section

UTILIZATION AND AVAILABILITY OF ASBESTOS IN ELECTRIC INSULATION

Oliver Bowles[1]

Introduction

Asbestos holds an unique position in the mineral kingdom. It is a naturally fibrous mineral that has some of the characteristics of silk, cotton, or rayon but differs from them in that it will not burn. Because it combines the properties of an unburnable fabric with other advantageous qualities, asbestos has specialized uses for which no adequate substitutes are yet available. Asbestos furnishes raw material for a great variety of essential products, manufacture of which constitutes a vast industry. The value of asbestos products manufactured in the United States during 1947, the latest year for which statistics are available, exceeded $274,000,000.

Asbestos may be defined as a fibrous form of either serpentine or amphibole. The serpentine variety, named chrysotile ($3MgO, 2SiO_2, 2H_2O$), is the principal variety of commerce. Amphibole varieties, such as tremolite, anthophyllite, amosite, and crocidolite, are unimportant from the standpoint of electrical insulation.

Electrical Uses

Asbestos is a widely recognized building material in such products as asbestos-cement roofing and siding. It is well known as a constituent of heat-insulating and fireproofing materials, such as pipe and boiler covering. Asbestos theater curtains and automobile brake linings are uses with which the general public is also familiar. The role of asbestos as an electric insulator is less widely known, and yet it is in that particular field that a critical situation occurred during World War II and has continued into the present period of military preparedness (1).

Asbestos is not selected for electrical applications because of superior dielectric properties; many other materials are better insulators. It is selected because its fibrous form and fire resistance adapt it peculiarly to certain important insulating uses. Unfortunately, most of the asbestos of commerce has poor insulating properties.

Restricted Supply of Low-Iron Chrysotile

Canadian chrysotile is eminently suited for nearly all major uses. Long, spinning grades make superior fabrics for brakebands, lagging cloth, and safety clothing. Shorter fibers are well adapted for building materials and heat-insulating products. However, for electric insulation—a small but important use—Canadian fiber is inferior because of its iron content.

The permissible iron content of asbestos for electrical insulation as given in Military Specifications MIL-I-3053A, dated August 3, 1951, is as follows:

Class	Maximum total iron, %	Maximum magnetic iron, %
2	2.5	0.75
4	4.0	2.0
6	6.0	4.0

[1] Consulting Commodity Specialist, U. S. Department of the Interior, Bureau of Mines, Washington, D. C.

Class 2 is intended only for special applications where the asbestos is of primary importance, such as electrical insulation on magnet wire, and certain tapes, sleeving, and cloth. Class 4 is intended for use where the asbestos is of secondary importance as an electrical insulator and where it is applied in combination with other materials of comparatively higher dielectric strength. Class 4 is suitable for cable coverings. Canadian asbestos in its natural state will rarely conform with the requirements of Classes 2 or 4. Class 6 is intended for use where the asbestos is of minor importance as a dielectric. Canadian asbestos will generally conform with the requirements of Class 6.

Only two areas in the world furnish marketable quantities of chrysotile satisfactory for Classes 2 or 4 electric insulation mentioned above: (*a*) the Shabani area in Southern Rhodesia, which furnishes chrysotile from which most of the iron can be removed with comparative ease; and (*b*) an area north of Globe, Arizona, from which a naturally low-iron fiber is obtained. Southern Rhodesia was the mainstay of the United States during World War II for necessary supplies of low-iron asbestos, which was urgently needed for electric cable coverings, especially on warships. Since the war, the supply situation has become more and more acute because the U. S. is receiving less and less fiber from this source. This stringent supply is due to increasing requirements for the fiber by Great Britain and other countries, and to inability of the mines to meet all needs adequately.

It has been mentioned previously that Arizona produces the most beautiful low-iron chrysotile in the world, but the output is small. For cable covering the fiber must not only be low in iron but also must be of spinning length, $\frac{3}{8}$-in. long or longer; only a small part of the output is of this grade. Furthermore, some of the fiber is too harsh and brittle for this exacting use. Moreover the deposits are scattered, and the fiber veins are commonly so discontinuous and widely spaced that mining costs are high. Even under stimulation, Arizona seems capable of producing only a few hundred tons a year of high grade fibers that will meet specifications, while United States needs are measured in thousands of tons.

Contrasting Types of Deposits

The Arizona occurrence differs widely from the Canadian. All major chrysotile deposits of the world, like the Canadian, consist of irregular crossfiber veins in massive serpentine. The deposits of Canada, Africa, and the Soviet Union cover large areas and extend to unknown depths. The Arizona deposits, on the other hand, occur as crossfiber veins in bedded limestones of limited thickness. Asbestos occurs only in the vicinity of diabase intrusions which evidently were factors in the origin of the fiber. Accordingly, such deposits tend to be restricted in size compared with the massive serpentine type.

In general, asbestos of the Canadian type contains considerable iron contamination. Asbestos deposits of Southern

Rhodesia, which, as stated previously, are the principal sources of low-iron asbestos, are of this type, and in their natural state the fibers contain several per cent of iron minerals. However, the iron is less intimately associated with the fibers than in other regions, and during the milling process most of the iron content is separated and removed. Contrasted with the occurrences in massive serpentine, deposits of the Arizona type, consisting of bedded veins in limestone, are generally very low in iron.

From the standpoint of electrical adaptability it appears, therefore, that the mass-serpentine types of deposits, although large in extent, are generally inferior in quality, and the bedded-vein types in limestone are generally of good quality but of small size.

Distribution of Arizona-Type of Deposits

In its search for sources of low-iron fiber, the Bureau of Mines has given considerable attention to the potentialities of deposits in limestone. Such deposits are uncommon and widely scattered. Some are too small for use. Their greatest development is in Arizona, and continued exploration may yet uncover deposits of moderate extent.

Similar deposits are known in other areas. One has been found at the top of a mountain in Death Valley, California, one in Madison County, Montana, and one in Warren County, New York. Small loans from Defense Minerals Exploration Administration were expended in exploratory work on two of these deposits, but they were found to be too small to merit commercial development.

Information has been assembled also on foreign deposits of this type. One such deposit exists at Lobatsi, Bechuanaland; one near Cuddapah, India; one at N'Cob, Morocco; and one in the Carolina district, Union of South Africa. None of them bears promise of substantial supplies. Recently information has been obtained that such deposits are known in Quebec, Canada, and steps are being taken to determine their extent and quality.

Important new discovery.—A recent development of unusual interest is the discovery of a large deposit of chrysotile asbestos of good spinning quality in northern British Columbia. It is now being developed by Cassiar Asbestos Corporation of Toronto. According to reports by the company and by other qualified observers, the percentage of long spinning fibers is unusually high. The deposit consists in part of a talus slope where large quantities of fiber lie exposed at the surface. The bedrock below the talus is said to be rich in fiber. Samples tested by an asbestos-textile-manufacturing company in the U. S. were found to be of good spinning quality; iron content, after preliminary fiber preparation, was found to be low enough for the material to qualify as a nonferrous fiber. A mill had been built and commercial production was begun last year.

Certain handicaps must be overcome before the enterprise can be established on a sound commercial basis. The deposit is at a 6000-ft altitude in the far north where the climate is severe. Furthermore, the location is far from consuming centers, and transportation is hazardous and costly. Because of the large size of the deposit and the high quality of the fiber therein, this discovery ranks as the most important that has been announced during recent years. It is a promising source of low-iron asbestos.

Methods of Meeting a Shortage of Supply

Faced with a critical situation involving an increasing demand for a strategic commodity the supply of which is diminishing, both the U. S. Government and industry have recognized the urgency of seeking a solution to the problem. The four following lines of approach are available: (*a*) active measures to secure larger supplies of low-iron asbestos; (*b*) development of methods for removal of iron from high-iron fiber to a point where it will satisfy low-iron specifications; (*c*) development of substitutes for low-iron asbestos; and (*d*) manufacture of low-iron asbestos by synthetic processes. Work has been done in all of these fields during recent years, and the accomplishments and present status of the problems are outlined below.

Steps to increase supply.—The Defense Minerals Exploration Administration has made loans on a cooperative basis to several companies for exploratory work in Arizona in the hope that larger supplies of soft spinning fiber may become available. Several projects are under way, but no results of promise are yet available. The Bureau of Mines Experiment Station at Tucson, Arizona, is assisting operators. Private industry is also carrying on exploratory and development work in Arizona.

The DMEA has also made loans for work on undeveloped asbestos deposits in California and other states. These projects have as yet yielded small returns.

As mentioned previously, the Bureau of Mines is alert in following up all information that becomes available on low-iron asbestos deposits anywhere in the world.

Efforts have been made both by government and industry to procure larger supplies from the single producer of low-iron chrysotile in Southern Rhodesia, but very little success has yet been attained. Several new operators are coming into production in Southern Rhodesia, and, although little is known of the quality of their products, they are potential supplementary sources.

De-ironing high-iron asbestos.—Since the objection to Canadian asbestos for electrical uses is its high iron content, an obvious solution of the problem is removal of the iron. This, however, is difficult because the iron minerals are very intimately associated with the asbestos; part of the iron content may, in fact, be intergrown with the fibers. Two asbestos companies have devoted much research to this problem. The Johns-Manville Company has conducted research for some years on de-ironing short-fiber Canadian chrysotile and now operates a mill at Tilton, New Hampshire, for making a series of products known as Quinterra papers (2). These products are applied to certain electric-insulation uses. Raybestos-Manhattan, Inc., of Manheim, Pennsylvania, has conducted research on de-ironing long-fiber Canadian chrysotile and has made a series of low-iron papers and tapes having the trade name Novabestos. The General Electric Company has also developed a process for removing conducting particles from asbestos and has used the purified fiber for making an inorganic paperlike sheet known as "Terratex" (3), suitable for certain high-temperature electric-insulation uses. Neither Quinterra, Novabestos, nor Terratex has yet attained wide enough acceptance to permit its substitution for standard low-iron fibers imported from Southern Rhodesia in their major insulating applications.

The Naval Research Laboratory has made some progress in de-ironing Canadian fiber by means of a paper-maker's Vortrap. Essentially, the separation is effected by the swirling action that results when rapidly flowing water is introduced into a pipe in a tangential direction. Centrifugal force tends to throw the heavy magnetite against the walls, where it settles to an outlet, while the asbestos fibers, freed to some

Current Affairs

Udy and Hackerman to Take Office in Chicago

MARVIN J. UDY

NORMAN HACKERMAN

As a result of the recent annual election, in which the voting is by mail ballot, Marvin J. Udy will be the new President of the Society and Norman Hackerman has been elected Vice-President. The new officers will be presented to the members and will formally take office at the annual business meeting of the Society, which will take place following the Society Luncheon, on Tuesday, May 4, at the Chicago Meeting.

Mr. Udy, consultant in metallurgical and electrochemical engineering, Niagara Falls, New York, replaces Mr. Robert J. McKay, Corrosion Laboratory, Department of Metallurgy, Massachusetts Institute of Technology, Cambridge. Mr. McKay, as Past President, will continue as a member of the Board of Directors.

Dr. Norman Hackerman, professor of chemistry, chairman of the department, and director of the Corrosion Research Laboratory at the University of Texas, Austin, Texas, will start his first term as Society Vice-President and will serve with the two previously elected Vice-Presidents, H. H. Uhlig and Hans Thurnauer. Dr. Hackerman has been Technical Editor of the JOURNAL since 1950.

See Your Program Booklet

Complete details of the Chicago Meeting schedule will be found in the Program Booklet which has been mailed to all Society members. Dates of the meeting are May 2–6, with headquarters at the LaSalle Hotel.

Guest Speaker

Casper W. Ooms, former U. S. Commissioner of Patents, will address the Society Luncheon on Tuesday, May 4. He will speak on "The Patent Problem in Atomic Energy Legislation."

Chicago Technical Program

Monday, May 3, 1954

9:00 A.M.—Formal Opening of the 105th Convention, with Introduction by General Chairman Howard T. Francis and response by President R. J. McKay.

Electric Insulation

Monday, May 3, 1954

Electrophysics

C. F. Miller presiding

9:30 A.M.—"Experiments Concerning the Infrared Goniometric Reflectance Characteristics of Metallic Surfaces" by John T. Agnew and Richmond B. McQuistan, Purdue University, Lafayette, Ind., and Leon L. Deer, U. S. Naval Ordnance, Indianapolis, Ind.

10:10 A.M.—"Paramagnetic Resonance with Some Applications to Problems in Chemistry and Physics" by Clyde A. Hutchison, Jr., Institute for Nuclear Studies, University of Chicago, Chicago, Ill.

10:50 A.M.—"Reduction of Oxidation-Ions in Hydrocarbons" by Andrew Gemant, Engineering Laboratory and Research Department, The Detroit Edison Company, Detroit, Mich.

11:20 A.M.—"Electrostatic Properties of Charged Dielectric Sheets" by H.T. McLean, General Engineering Laboratory, General Electric Company, Schenectady, N. Y.

Electric Insulation (cont'd)
Dielectric Liquids

C. F. Miller presiding

2:10 P.M.—"Transformer Oil: Properties of Naphthenic and Aromatic Fractions" by R. Nichols Hazelwood, Raymond M. Frey, and Joanne B. Broecker, Line Material Company (A McGraw Electric Company Division), South Milwaukee, Wis.

2:50 P.M.—"Dielectric Dispersion of Mixtures of Chlorinated Biphenyls with Trichlorobenzene and with

Diphenyl Ether" by Robert J. Good, Department of Applied Science, University of Cincinnati, Cincinnati, Ohio.

3:30 P.M.—"Stabilization of Dielectrics" by D. A. McLean, Bell Telephone Laboratories, Inc., Murray Hill, N. J.

4:10 P.M.—"Electrical Properties of Commercial Liquid Dielectrics" by Thomas D. Callinan, Naval Research Laboratory, Washington, D. C.

Tuesday, May 4, 1954
Electric Insulation (cont'd)
R. A. Ruscetta presiding

9:00 A.M.—"Recent Developments in Integrated Mica" by M. D. Heyman, Integrated Mica Corporation, Woodmere, L. I., N. Y.

9:40 A.M.—"Electrical Properties of 'Araldite' Ethoxyline Resins" by M. Wismer and J. Durra, Ciba Corporation, New York, N. Y.

10:20 A.M.—"Du Pont 'Mylar' Polyester Film, A New and Versatile Electrical Insulation" by J. A. Ruby, Sales Development and Technical Service, E. I. du Pont de Nemours & Company, Inc., Wilmington, Del.

11:00 A.M.—"'Bakelite' Cellular Polyethylene" by W. T. Higgins, Bakelite Company, Division of Union Carbide & Carbon Corporation, Bound Brook, N. J.

11:40 A.M.—"Applications of Isocyanates in the Electrical Industry" by J. H. Saunders and Edgar E. Hardy, Monsanto Chemical Company, Anniston, Ala.

Electric Insulation (cont'd)
Round-Table Discussion
Casting and Potting Compounds
L. L. Deer presiding

2:00 P.M.—The panel will include representatives from both the material manufacturers and users and will discuss the problems that confront the industry.

"*New Casting Resins for Miniaturization*" by P. Rector, National Engineering Products Company, Washington, D. C.

Wednesday, May 5, 1954
Electric Insulation (cont'd)
D. A. Lupfer presiding

9:00 A.M.—"Aging Characteristics of Class 'H' Insulation" by Edwin Lotz, Coating Division, Irvington Varnish and Insulator Company, Irvington, N. J.

9:40 A.M.—"More Advantageous Use of Layer Insulations from Thickness-Dielectric Strength Relationships" by Paul Doigan, Materials and Processes Laboratory, General Electric Company, Pittsfield, Mass.

10:20 A.M.—"Survey of Arc-Resistance and Tracking Characteristics of Plastics" by W. C. Wikstrand and C. F. Spiers, Research Laboratory, American Cyanamid Company, Stamford, Conn.

11:00 A.M.—"Effect of Moisture, Temperature, and Frequency on the Electrical Properties of Insulating Materials" by L. J. Frisco, Dielectrics Laboratory, The Johns Hopkins University, Institute for Cooperative Research, Baltimore, Md.

11:40 A.M.—"Breakdown Phenomena as Related to Other Dielectric Properties" by J. J. Chapman, Dielectrics Laboratory, The Johns Hopkins University, Institute for Cooperative Research, Baltimore, Md.

Electric Insulation (cont'd)
D. A. Lupfer presiding

2:00 P.M.—"Review of Metal-Ceramic Seals" by Hayne Palmour, III, American Lava Corporation, Chattanooga, Tenn.

2:40 P.M.—"Review of High Temperature Insulations Including Varnished Cloths, Mica Paper, and Other Sheet Materials" by A. J. Sherburne and R. W. Staley, General Electric Company, Coshocton, Ohio.

Electronics—Instrumentation

Tuesday, May 4, 1954
A. E. Martin presiding

2:00 P.M.—Introductory remarks by A. E. Martin.

2:05 P.M.—"Stabilized Power Supplies for Instrument Applications" by W. G. Amey, F. H. Krantz, W. R. Clark, and A. J. Williams, Jr., Research Department, Leeds & Northrup Company, Philadelphia, Pa.

2:35 P.M.—"High-Frequency Instrumentation" by J. C. Clayton, J. Fred Hazel, Wallace M. McNabb, and G. L. Schnable, Department of Chemistry, University of Pennsylvania, Philadelphia, Pa.

3:35 P.M.—Intermission.

3:05 P.M.—"Measurement of Fluorescence Decay Times" by S. H. Liebson, Electricity Division, Naval Research Laboratory, Washington, D. C.

3:45 P.M.—"Measurement of Color Uniformity of Black and White Kinescope Screens" by Austin E. Hardy, Tube Department, Radio Corporation of America, Lancaster, Pa.

4:15 P.M.—"Photoelectric Tristimulus Methods of Phosphor Color Measurement" by Richard S. Hunter, Hunter Associates Laboratory, Falls Church, Va.

Electronics—Luminescence

Monday, May 3, 1954
C. W. Jerome presiding

9:15 A.M.—Keynote address—"Luminescence Facts and Foibles" by Humboldt W. Leverenz, RCA Laboratories, Princeton, N. J.

9:45 A.M.—"Heat Treatment of Zinc Sulfide Single Crystals" by Alfred Kremheller, Physics Laboratories, Sylvania Electric Products Inc., Bayside, N. Y.

10:10 A.M.—"Adsorption of Precipitated Zinc Sulfide for Chloride and Sulfate Ions" by Dominic T. Palumbo, Physics Laboratories, Sylvania Electric Products Inc., Bayside, N. Y., and Albert K. Levine, Department of Chemistry, Brooklyn College, Brooklyn, N. Y., and Sylvania Electric Products Inc., Bayside, N. Y.

10:35 A.M.—"Examination of the Role of Fluxes in Zinc Sulfide Phosphor Preparation" by Paul Goldberg, Physics Laboratories, Sylvania Electric Products Inc., Bayside, N. Y., and Albert K. Levine, Department of Chemistry, Brooklyn College, Brooklyn N. Y., and Sylvania Electric Products Inc., Bayside, N. Y.

11:00 A.M.—"Surface States of Cadmium Sulfide" by S. H. Liebson, Electricity Division, Electromagnetics Branch, Naval Research Laboratory, Washington, D. C.

11:30 A.M.—"Luminescence of Zinc Sulfide Phosphors" by Laurence Burns, Sylvania Electric Products Inc., Salem, Mass.

12:00 M.—"A Model for Luminescence and Conductivity in Sulfides" by Clifford C. Klick, Chemistry Branch, Metallurgy Division, and John Lambe Electromagnetics Branch, Electricity Division, Naval Research Laboratory, Washington, D. C.

Electronics—Luminescence (cont'd)
Robert J. Ginther presiding

2:00 P.M.—"Trapping in ZnS:Cu:Co" by B. Goldstein and J. J. Dropkin, Polytechnic Institute of Brooklyn, Brooklyn, N. Y.

2:30 P.M.—"Temperature Dependence of the Fluorescence of ZnS Phosphors" by Spotswood D. Bowers, Jr., United States Radium Corporation, Bloomsburg, Pa.

3:00 P.M.—"Some Electroluminescent Effects and Their Interpretation" by

Frank Matossi and Sol Nudelman, U. S. Naval Ordnance Laboratory, White Oak, Md.

3:30 P.M.—"Electroluminescence in ZnS Single Crystals" by W. R. Watson and A. T. Halpin, Physics Laboratories, Sylvania Electric Products Inc., Bayside, N. Y., and J. J. Dropkin, Polytechnic Institute of Brooklyn, Brooklyn, N. Y., and Sylvania Electric Products Inc., Bayside, N. Y.

4:00 P.M.—"Increase of Luminescence Sensitivity to X-Rays of Some Mixtures of Zinc Sulfide and Cadmium Sulfide under the Action of Alternating Electric Fields" by G. Destriau, Consultant, Westinghouse Electric Corporation, Bloomfield, N. J., and Faculté des Sciences de Paris, France.

4:30 P.M.—"Electroluminescent Lamps Using Glass Dielectrics" by Richard M. Rulon, Sylvania Electric Products Inc., Salem, Mass.

Tuesday, May 4, 1954
Electronics—Luminescence (cont'd)
J. J. Dropkin presiding

9:00 A.M.—"Modified Calcium Pyrophosphate Phosphors" by D. E. Kinney, Chemical Products Works, General Electric Company, Cleveland, Ohio.

9:25 A.M.—"Emission Spectrum of CaF_2:(Ce + Mn)" by Robert J. Ginther, Chemistry Branch, Metallurgy Division, Naval Research Laboratory, Washington, D. C.

9:50 A.M.—"Antimony Oxide Phosphor with Red Emission" by Yoshihide Kotera and Tadao Sekine, Fifth Division, Government Chemical Industrial Research Institute, Tokyo, Japan.

10:15 A.M.—"Lanthanum Oxychloride Phosphors" by Frank E. Swindells, Photo Products Department, E. I. du Pont de Nemours & Company, Inc., Parlin, N. J.

10:40 A.M.–12:30 P.M.—Round-Table Discussion.

Electronics—Phosphor Screen Application

Wednesday, May 5, 1954
A. Steadman presiding

9:00 A.M.—Introductory remarks by A. Steadman.

9:05 A.M.—"Some Factors Affecting Screening and Screen Strength in Cathode Ray Tubes" by J. Fred Hazel, Department of Chemistry, University of Pennsylvania, Philadelphia, Pa., and William Stericker, Philadelphia Quartz Company, Philadelphia, Pa.

9:30 A.M.—"Interaction of Barium Salts with Potassium Silicate Solutions" by J. Fred Hazel, Wallace M. McNabb, and C. A. Crutchfield, Jr., Department of Chemistry, University of Pennsylvania, Philadelphia, Pa.

10:00 A.M.—"A Study of Barium and Silicate Concentrations in Phosphor Screen Application" by Russell B. Snyder and Leonard Maisel, Allen B. Du Mont Laboratories, Inc., Clifton, N. J.

10:35 A.M.—"Secondary Electron Emission of All-Sulfide Phosphor Screens" by G. P. Kirkpatrick, Radio Corporation of America, Lancaster, Pa.

11:00 A.M.—"Use of Screen Potential Measurement Equipment in Evaluating Cathode Ray Tube Screens" by T. V. Rychlewski and L. W. Evans, Sylvania Electric Products Inc., Seneca Falls, N.Y.

11:25 A.M.—"Filming and Aluminizing Processes for Cathode Ray Tubes" by Channing Dichter and Vanja Srepel, General Electric Company, Syracuse, N. Y.

Round Table
Electronics—Phosphor Screen Application (cont'd)
Marvin Rathfelder presiding

2:00–5:00 P.M.—Round-Table Discussion. Speakers will include C. Dichter, A. Hardy, J. Fred Hazel, E. C. Larsen, M. Sadowsky, A. Steadman, and L. T. Weagle.

Joint Session Electronics-Rare Metals—Electrothermics

Thursday, May 6, 1954
Refractory Compounds
J. H. Westbrook presiding

9:00 A.M.—"Metallic Composites" by J. Wulff, Department of Metallurgy, Massachusetts Institute of Technology, Cambridge, Mass.

9:20 A.M.—"Preparation of Refractory Compounds Having Controlled Microstructure" by R. Atkinson, R. Read, and A. J. Shaler, Department of Mineral Technology, Pennsylvania State College, State College, Pa.

9:40 A.M.—"Temperature Dependence of Hardness of the Equi-Atomic Iron Group Aluminides" by J. H. Westbrook, Research Laboratory, General Electric Company, Schenectady, N. Y.

10:00 A.M.—"Disilicides—New Refractory Alloys" by Roger A. Long, Aircraft Components Division, Ferrotherm, Cleveland, Ohio.

10:20 A.M.—"Titanium Silicide as a Refractory Coating" by Stanley Kluz, Ralph Wehrmann, and L. F. Yntema, Fansteel Metallurgical Corporation, North Chicago, Ill.

10:40 A.M.—"Physical Properties of Transition Metal Diborides" by Frank W. Glaser and David Moskowitz, American Electro Metal Corporation, Yonkers, N. Y., and Benjamin Post, Polytechnic Institute of Brooklyn, Brooklyn, N. Y.

11:00 A.M.—"Preparation and Crystal Structures of Some High Melting Thorium-Germanium Compounds" by A. W. Searcy and A. G. Tharp, Purdue University, Lafayette, Ind.

11:20 A.M.—"Resistance Sintering under Pressure of Refractory Materials" by F. V. Lenel, Department of Metallurgical Engineering, Rensselaer Polytechnic Institute, Troy, N. Y.

11:40 A.M.—"Electrothermal Heating of Solutions" by Kenneth A. Kobe, University of Texas, Austin, Texas, and Carl J. Carlson, Standard Oil Company of California, Avenal, Calif.

Joint Session (cont'd)
Electronics-Rare Metals—Electrothermics (cont'd)
Refractory Metals
A. U. Seybolt presiding

2:00 P.M.—"Determination of the Gas Content of Metals of High Purity by Vacuum Fusion" by M. W. Mallett, Battelle Memorial Institute, Columbus, Ohio.

2:20 P.M.—"An Investigation of the Hydrogen Chloride Volatilization Method for the Analysis of Oxygen in Zirconium" by Russell H. Atkinson, Lamp Division, Westinghouse Electric Corporation, Bloomfield, N. J.

2:40 P.M.—"Recent Investigations in the Control and Operation of Zirconium Production Furnaces" by F. E. Block and A. D. Abraham, Bureau of Mines, U. S. Department of the Interior, Albany, Oreg.

3:00 P.M.—"Crystal Structure and Thermodynamic Studies on Zirconium-Hydrogen Alloys" by Earl A. Gulbransen and Kenneth F. Andrew, Westinghouse Research Laboratories, East Pittsburgh, Pa.

3:20 P.M.—"Diffusion of Hydrogen in High Purity Zirconium" by Earl A. Gulbransen and Kenneth F. Andrew, Westinghouse Research Laboratories, East Pittsburgh, Pa.

3:40 P.M.—"Room-Temperature Ductile Chromium" by H. Johansen and G. Asai, Bureau of Mines, U. S. Department of the Interior, Albany, Oreg.

4:00 P.M.—"A Metallurgical Evaluation of Iodide Chromium" by D. J. Maykuth, W. D. Klopp, R. I. Jaffee, and H. B. Goodwin, Battelle Memorial Institute, Columbus, Ohio.

4:20 P.M.—"Preparation of High Purity Thorium by the Iodide Process" by N. D. Veigel, E. M. Sherwood, and I. E. Campbell, Battelle Memorial Institute, Columbus, Ohio.

4:40 P.M.—"High Temperature Crystal Structure of Thorium" by P. Chiotti, Iowa State College, Ames, Iowa.

5:00 P.M.—"Vapor Pressure of Rhenium" by D. M. Rosenbaum, E. M. Sherwood, J. M. Blocher, Jr., and I. E. Campbell, Battelle Memorial Institute, Columbus, Ohio.

Electronics—Semiconductors

Wednesday, May 5, 1954
Intermetallic Compounds
A. E. Middleton presiding

9:00 A.M.—Introductory remarks by A. E. Middleton.

9:05 A.M.—Keynote Address—"Semiconductor Research and Development in Germany" by Herbert F. Matare, Intermetal Corporation, New York, N. Y.

9:45 A.M.—"Electrical Properties of Some Group III-Group V Compounds" by H. J. Hrostowski and M. Tanenbaum, Bell Telephone Laboratories, Inc., Murray Hill, N. J.

10:15 A.M.—"Band Separation of a Number of Semiconducting Compounds from Optical Data" by Richard W. Koch, James F. Miller, and Harvey L. Goering, Battelle Memorial Institute, Columbus, Ohio.

10:45 A.M.—"Preparation and Electrical Properties of Lead Sulfide" by W. W. Scanlon and R. E. Brebrick, U. S. Naval Ordnance Laboratory, White Oak, Md.

11:15 A.M.—"Semiconducting Films, II. InSb Films" by I. Dietrich and K. Lark-Horovitz, Department of Physics, Purdue University, Lafayette, Ind.

11:45 A.M.—"Periodic Relations in the Properties of Semiconducting Compounds" by R. W. Douglas, Research Laboratories, The General Electric Company, Inc. Wembley, England.

Electronics—Semiconductors (cont'd)
Intermetallic Compounds and Germanium and Silicon
J. A. Burton presiding

2:00 P.M.—"Growth and Orientation of Crystals of the Diamond and Zinc Blende Type" by G. Wolff, Signal Corps Engineering Laboratories, Ft. Monmouth, N. J.

2:30 P.M.—"Crystallization of Silicon from a Floating Liquid Zone" by Paul H. Keck, Signal Corps Engineering Laboratories, Ft. Monmouth, N. J.

3:00 P. M.—"High Purity Silicon" by Felix B. Litton and Holger C. Andersen, Research and Development Laboratories, Foote Mineral Company, Berwyn, Pa.

3:30 P.M.—"Preparation and Properties of Germanium-Silicon Alloys" by C. C. Wang and B. H. Alexander, Electronics Division, Sylvania Electric Products Inc., Ipswich, Mass.

4:00 P.M.—"Semiconducting Films, I. Germanium Films" by M. Becker and K. Lark-Horovitz, Department of Physics, Purdue University, Lafayette, Ind.

4:30 P.M.—"Preparation of *N-P*-Junctions in Germanium by Surface Melting, and Their Electrical Properties" by K. Lehovec, A. Webb, and R. Zuleeg, Sprague Electric Company, North Adams, Mass.

Thursday, May 6, 1954

Electronics—Semiconductors (cont'd)
Germanium and Silicon
J. R. Musgrave presiding

9:00 A.M.—"Electrolytic Stream Etching of Germanium" by Miles V. Sullivan, Bell Telephone Laboratories, Inc., Murray Hill, N. J.

9:30 A.M.—"A Study of the Etching Rate of Single Crystal Germanium" by Paul R. Camp, RCA Laboratories Division, Radio Corporation of America, Princeton, N. J.

10:00 A.M.—"Investigations of Surface Recombination Velocities on Germanium by the Photo-Electromagnetic Method" by T. M. Buck and W. H. Brattain, Bell Telephone Laboratories, Inc., Murray Hill, N. J.

10:30 A.M.—"On the Behavior of Rapidly Diffusing Acceptors in Germanium" by F. van der Maesen and J. A. Brenkman, Philips Research Laboratories, N. V. Philips' Gloeilampenfabrieken, Eindhoven, Holland.

11:00 A.M.—"Ultrasonic Attenuation Measurements in Germanium and Silicon Single Crystals" by A. Granato and Rohn Truell, Brown University, Providence, R. I.

11:30 A.M.—"Electrical Properties of Microscopic Crystals of Boron and Germanium" by Wm. C. Shaw, Midwest Research Institute, Kansas City, Mo.

Electronics—Semiconductors (cont'd)
Semiconductor Devices and Other Semiconductors
Paul H. Keck presiding

2:00 P.M.—"'Stabilized Breakdown' Phenomenon in Selenium Rectifiers" by A. C. English, P. J. Colleran, A. Just, and W. H. Tobin, General Electric Company, Schenectady, N.Y.

2:30 P.M.—"The Evaluation of New Semiconductors for Transistors and Application to Gallium Antimonide" by D. A. Jenny, RCA Laboratories Division, Radio Corporation of America, Princeton, N. J.

3:00 P.M.—"The Photoconduction of Zinc Oxide: A Study of Chemisorption" by P. H. Miller, Jr., and D. A. Melnick, Randal Morgan Laboratory of Physics, University of Pennsylvania, Philadelphia, Pa.

3:30 P.M.—"Titanium Dioxide Rectifiers: Production Methods and Electrical Properties" by T. S. Shilliday and C. S. Peet, Battelle Memorial Institute, Columbus, Ohio.

4:00 P.M.—"Germanium Area Photovoltaic Cells" by Edward Simon, Department of Physics, Purdue University, Lafayette, Ind.

4:30 P.M.—"Stabilization and Matching of Germanium Diodes for Military Applications" by W. F. Haldeman, Navy Department, U. S. Naval Ordnance Plant, Indianapolis, Ind.

Electrothermics

Tuesday, May 4, 1954
The Electric Arc Furnace (Excluding Steel Making)
Section I—Design and Construction
A. C. Haskell, Jr., General Chairman
E. T. Johnson presiding

9:15 A.M.—Various types of furnaces such as the tilting, rotating hearth, submerged arc, and inert atmosphere types will be described as used for making ferrous and nonferrous alloys and other nonferrous products, both in this country and in Europe. The major features of each will be presented and discussed. The important factors influencing the design and choice of the arc furnace will be considered.

Electrothermics (cont'd)
The Electric Arc Furnace (cont'd) (Excluding Steel Making)
Section II—Electrical Equipment
A. C. Haskell, Jr., General Chairman
J. J. Pannabaker presiding

2:00 P.M.—With a simplified wiring diagram as a background, papers will be presented on the three major components of the electrical system, namely, (*a*) breakers, (*b*) transformers and (*c*) controls. In addition to the description of the assemblies and subassemblies, the function and interrelationship of each will be discussed with special emphasis given to the very severe conditions imposed by the rapidly and widely fluctuating load.

Wednesday, May 5, 1954
Electrothermics (cont'd)
The Electric Arc Furnace (cont'd)
(Excluding Steel Making)
Section III—Electrodes
A. C. Haskell, Jr., General Chairman
John A. Shaw presiding

9:15 A.M.—Following a brief description of the three major types of electrodes (amorphous carbon, graphite, and Soderberg) and their manufacture, the characteristics of each type will be discussed, with special reference to current-carrying capacity and the effects of different shapes. The papers will deal additionally with electrical, thermal, and weight losses, showing how and why they occur and suggested methods for minimizing.

Electrothermics (cont'd)
The Electric Arc Furnace (cont'd)
(Excluding Steel Making)
Section IV—Applications
A. C. Haskell, Jr., General Chairman
Gordon R. Finlay presiding

11:00 A.M.—This section will deal with a few of the products manufactured in the arc furnace. Some of the reactions going on in the furnace and the nature of the reactants or products will be described.

2:00 P.M.—Section IV—Applications continued.

Electrothermics (cont'd)
The Electric Arc Furnace (cont'd)
(Excluding Steel Making)
Section V—Theory of Arcs
A. C. Haskell, Jr., General Chairman
George W. Healy presiding

2:45 P.M.—The nature and characteristics of the arc will be reviewed briefly, including a discussion of the various phenomena at the cathode and anode and in the arc column itself. In addition to the theoretical aspects, experimental work will be presented relating to the wave forms of the arc current and voltage and their dependence on the arc atmosphere and electrode composition.

Thursday, May 6, 1954
Joint Session
Electrothermics—Rare Metals
Refractory Compounds
J. H. Westbrook presiding

9:00 A.M.–12:00 M.—See p. 97C for the papers on the Joint Session with Electronics—Rare Metals.

Joint Session (cont'd)
Electrothermics—Rare Metals
(cont'd)
Refractory Metals
A. U. Seybolt presiding

2:00 P.M.–5:30 P.M.—See p. 97C for the papers on the Joint Session with Electronics—Rare Metals.

Industrial Electrolytic

Monday, May 3, 1954
Frederick W. Koerker presiding

9:30 A.M.—"Explosive Limits of Hydrogen-Chlorine Mixtures" by A. W. Umland, The Dow Chemical Company, The Texas Division, Freeport, Texas.

9:50 A.M.—"Diaphragm Type Amalgam Caustic-Chlorine Cell" by Charles Potter and A. L. Bisio, Department of Chemical Engineering, Columbia University, New York, N. Y.

10:10 A.M.—"The *p*H in Chlorine-Caustic Electrolysis by the Mercury Cell Process" by Lars Barr, Division of Applied Electrochemistry, Royal Institute of Technology, Stockholm, Sweden.

10:30 A.M.—"The Effect of Impurities in the Electrolysis of Sodium Chloride Solution by Mercury Process" by Shinzo Okada and Shiro Yoshizawa, Department of Industrial Chemistry, Faculty of Engineering, Kyoto University, Yosida, Kyoto, Japan.

10:50 A.M.—"Several Problems Concerning the Current Distribution in the Industrial Electrolyzer" by Shinzo Okada, Shiro Yoshizawa, and Fumio Hine, Department of Industrial Chemistry, Faculty of Engineering, Kyoto University, Yosida, Kyoto, Japan.

11:10 A.M.—"Continuous and Uniform Generation of Stibine; An Electrolytic Apparatus and Method" by Arnold Reisman, Melvin Berkenblit, E. C. Haas, and Allison Gaines, Jr., Material Laboratory, New York Naval Shipyard, Brooklyn, N. Y.

11:30 A.M.—"An Electrolytic Cell for Regeneration of Chromic Acid" by J. D. Fitzpatrick and R. P. Rolfes, Emery Industries, Inc., Cincinnati, Ohio.

Industrial Electrolytic (cont'd)
Round-Table Discussion
Frederick W. Koerker presiding

2:00–5:00 P.M.—Summary of Chlorine-Caustic Production by W. C. Gardiner, Mathieson Chemical Corporation, Niagara Falls, N. Y.

"Chlorine and other Halogen Compression" R. B. MacMullin Associates, Niagara Falls, N. Y., will introduce the subject with an historical review, and they have contacted manufacturers and others to present 15-minute informal discussions of particular equipment. No formal papers for publication will be presented, and there will be no transcript of the meeting. The outline includes various phases of wet and dry chlorine gas compression, liquid chlorine pumping, and compression of other halogen gases. Discussions on hydraulic compression; diaphragm, sulfuric acid seal, and nonlubricated reciprocating compressors; liquid ring seal compressors; centrifugal machines; and ejectors are suggested phases. Discussions and questions from the floor will be invited.

Tuesday, May 4, 1954
Industrial Electrolytic (cont'd)
Molten Bath Electrolysis
Frederick W. Koerker presiding

9:00 A.M.—Introduction—"Fused Salt Electrolysis" by Seymour Senderoff, Electrodeposition Section, Division of Chemistry, National Bureau of Standards, U. S. Department of Commerce, Washington, D. C.

9:20 A.M.—"Cathode Processes in Aluminum Reduction" by Morris Feinleib, Kaiser Aluminum & Chemical Corporation, Permanente, Calif.

9:40 A.M.—"Electrical Conductivity and Density of Molten Cryolite with Additives" by Junius D. Edwards, Cyril S. Taylor, Lee A. Cosgrove, and Allen S. Russell, Aluminum Research Laboratories, Aluminum Company of America, New Kensington, Pa.

10:00 A.M.—"Baths of Low Alumina Concentration in the Electrolysis of Aluminum" by Y. Doucet, Faculty of Sciences, Dijon University, Paris, France, L. Ferrand, Consulting Engineer, Paris, France, and F. V. Andreae, 351 Derby Circle, Chattanooga, Tenn.

10:20 A.M.—"The Extractive Metallurgy of Zirconium by the Electrolysis of Fused Salts, II. Process development of the Electrolytic Production of Zirconium from K_2ZrF_6" by M. A. Steinberg, M. E. Sibert, and E. Wainer, Horizons Incorporated, Cleveland, Ohio.

10:40 A.M.—"The Extractive Metallurgy of Zirconium by the Electrolysis of Fused Salts, III. Large Scale and Pilot Plant Production" by B. C. Raynes, E. Thellmann, M. A. Steinberg, and E. Wainer, Horizons Incorporated, Cleveland, Ohio.

11:00 A.M.—"The Electrolytic Preparation of Molybdenum from Fused Salts, II. Preparation of Reduced Molybdenum Halides" by Seymour Senderoff and Abner Brenner, Electrodeposition Section, Division of Chemistry, National Bureau of Standards, U. S. Department of Commerce, Washington, D. C.

11:20 A.M.—"The Electrolytic Preparation of Molybdenum from Fused Salts, III. Studies of Electrode Potentials" by Seymour Senderoff and Abner Brenner, Electrodeposition Section, Division of Chemistry, National Bureau of Standards, U. S. Department of Commerce, Washington, D. C.

11:40 A.M.—"The Electrolytic Preparation of Molybdenum from Fused Salts, IV. Preparation of Reduced Molybdenum Halides from Molybdenite Concentrate" by Seymour Senderoff and Roger J. Labrie, Electrodeposition Section, Division of Chemistry, National Bureau of Standards, U. S. Department of Commerce, Washington, D. C.

Industrial Electrolytic (cont'd)
Molten Bath Electrolysis (cont'd)
Titanium
Frederick W. Koerker presiding

2:00 P.M.—"Development of a Process for the Electrorefining of Titanium" by R. S. Dean and W. W. Gullett, Chicago Development Corporation, Riverdale, Md.

2:20 P.M.—"Electrode Reactions in the Refining of Titanium-Oxygen Alloys in Fused Chloride Baths" by R. S. Dean, W. W. Gullett, and Leo Goldenberg, Chicago Development Corporation, Riverdale, Md.

2:40 P.M.—"Preparation of Titanium by Electrolytic Reduction of the Reduced Oxides" by M. E. Sibert, Q. H. McKenna, M. A. Steinberg, and E. Wainer, Horizons Incorporated, Cleveland, Ohio.

3:00 P.M.—"Preparation of Titanium by Fluoride Electrolysis" by M. A. Steinberg, S. Carlton, M. E. Sibert, and E. Wainer, Horizons Incorporated, Cleveland, Ohio.

3:20 P.M.—"Anodic Behavior of Titanium in Fused Salt Baths" by M. E. Straumanis and A. W. Schlechten, Department of Metallurgical Engineering, University of Missouri, School of Mines and Metallurgy, Rolla, Mo.

3:40 P.M.—"Pyrosol Formation and Corrosion of Titanium in Fused Salts" by C. B. Gill, M. E. Straumanis, and A. W. Schlechten, Department of Metallurgical Engineering, University of Missouri, School of Mines and Metallurgy, Rolla, Mo.

4:00 P.M.—"Deposition of Titanium Coatings from Pyrosols" by A. W. Schlechten, M. E. Straumanis, and C. B. Gill, Department of Metallurgical Engineering, University of Missouri, School of Mines and Metallurgy, Rolla, Mo.

Theoretical Electrochemistry

Monday, May 3, 1954
Special Methods in Electrochemistry
Paul Fugassi presiding

9:30 A.M.—"Radio Tracer Studies of Electrolytic Action on Metal Surfaces" by Massoud T. Simnad, Metals Research Laboratory, Carnegie Institute of Technology, Pittsburgh, Pa.

10:00 A.M.—"Applications of Ultrasonic Waves in Theoretical Electrochemistry" by Ernest Yeager, Department of Chemistry, Western Reserve University, Cleveland, Ohio.

10:30–10:45 A.M.—Discussion.

10:45 A.M.—"Use of Isotopes in the Study of Ionic Hydration" by Henry Taube, Department of Chemistry, University of Chicago, Chicago, Ill.

11:15 A.M.—"Alternating Current Electrolysis" by A. E. Remick, Department of Chemistry, Wayne University, Detroit, Mich.

11:45 A.M.–12:00 M.—Discussion.

Theoretical Electrochemistry
(cont'd)
Special Methods in Electrochemistry
(cont'd)
Ernest Yeager presiding

2:00 P.M.—"Nuclear Magnetic Resonance as Applied to Electrolytic Solutions" by H. S. Gutowsky, Department of Chemistry, University of Illinois, Urbana, Ill.

2:30 P.M.—"Techniques for the Study of Hydrogen Electrode Kinetics" by J. O'M. Bockris, Department of Chemistry, University of Pennsylvania, Philadelphia, Pa.

3:00 P.M.—"Investigations of Equilibria in Concentrated Solutions by Means of Raman Spectra" by T. F. Young, Department of Chemistry, University of Chicago, Chicago, Ill.

3:30–3:45 P.M.—Discussion

3:45 P.M.—"Current Interrupter Techniques in the Study of Electrode Processes" by Sigmund Schuldiner, Naval Research Laboratory, Washington, D. C.

4:15 P.M.—"Application of Voltammetry at Constant Current to Electrochemical Studies" by Paul Delahay, Department of Chemistry, Louisiana State University, Baton Rouge, La.

4:45–5:00 P.M.—Discussion.

Tuesday, May 4, 1954
Theoretical Electrochemistry
(cont'd)
Ernest Yeager presiding

9:00 A.M.—"Dissociation of Acids in Aqueous Solution" by T. G. Owe Berg, Avesta Jernverks Aktiebolag, Avesta, Sweden.

9:25 A.M.—"Heats of Formation and Entropies of HS^- and $S^=$. Potential of Sulfide Sulfur Couple" by J. W. Kury, A. J. Zielen, and W. M. Latimer, Department of Chemistry and Chemical Engineering and Radiation Laboratory, University of California, Berkeley, Calif.

9:50 A.M.—"Electrolytic Oxidation of Zinc in Alkaline Solutions" by Thedford P. Dirkse, Department of Chemistry, Calvin College, Grand Rapids, Mich.

10:15 A.M.—"Evolution of Stibine at Antimony Cathodes" by H. W. Salzberg and A. J. Andreatch, Naval Research Laboratory, Washington, D. C.

10:40 A.M.—"Water Adsorption and Hydrogen Evolution" by H. W. Salzberg, Naval Research Laboratory, Washington, D. C.

11:05 A.M.—"Determination of Barrier Layer Thickness of Anodic Oxide Coatings" by M. S. Hunter and P. Fowle, Aluminum Research Laboratories, Aluminum Company of America, New Kensington, Pa.

11:30 A.M.—"Factors Affecting the Formation of Anodic Oxide Coatings" by M. S. Hunter and P. Fowle, Aluminum Research Laboratories, Aluminum Company of America, New Kensington, Pa.

Theoretical Electrochemistry
(cont'd)
Paul Delahay presiding

2:00 P.M.—"Measurement of Electrolytic Conductivity by Ballistic Galvanometer and Condenser: Applied to Aniline" by G. W. Thiessen and Students, Department of Chemistry, Monmouth College, Monmouth, Ill.

2:25 P.M. "Hydrogen Overvoltage on

Bright Platinum, II. *p*H and Salt Effects in Acid, Neutral, and Alkaline Solutions" by Sigmund Schuldiner, Electrochemistry Branch, Naval Research Laboratory, Washington, D. C.

2:50 P.M.—"Effect of Solvents and Electrolytes on Polarograms of Carbon Tetrachloride" by Johan J. Lothe and L. B. Rogers, Department of Chemistry and Laboratory for Nuclear Science, Massachusetts Institute of Technology, Cambridge, Mass.

3:15 P.M.—"Ionic Mass Transfer and Concentration Polarization at Rotating Electrodes" by M. Eisenberg, C. W. Tobias, and C. R. Wilke, Department of Chemistry and Chemical Engineering, University of California, Berkeley, Calif.

3:40 P.M.—"Electrochemical Polarization of Zirconium in Distilled Water" by Norman Hackerman and Otto L. Willbanks, Jr., Department of Chemistry, University of Texas, Austin, Texas.

4:05 P.M.—"Mechanism of the Copper-Arsenic Method of Purifying Zinc Sulfate Electrolyte" by G. R. Van Houten and L. E. Stout, School of Engineering, Washington University, Seattle, Wash.

4:30 P.M.—"Electrodeposition of Alkali Metals from Nonaqueous Solutions" by Harry C. Mandell, Jr., Wallace M. McNabb, and J. Fred Hazel, Department of Chemistry, University of Pennsylvania, Philadelphia, Pa.

Wednesday, May 5, 1954
Theoretical Electrochemistry (cont'd)
Paul Delahay presiding

9:00 A.M.—"Potentiometric Titration of Simple Salts with Potassium in Liquid Ammonia" by George W. Watt, Gregory R. Choppin, and James L. Hall, Department of Chemistry, University of Texas, Austin, Texas.

9:25 A.M.—"Potentiometric Titration of Ammines of Rhodium, Iridium, and Platinum with Solutions of Potassium and Potassium Amide in Liquid Ammonia" by George W. Watt, Gregory R. Choppin, and James L. Hall, Department of Chemistry, University of Texas, Austin, Texas.

9:50 A.M.—"Hydrogen Overvoltage Measurements on Platinum and Platinum Alloys" by Gerald Lozier, Ernest Yeager, and Frank Hovorka, Department of Chemistry, Western Reserve University, Cleveland, Ohio.

10:15 A.M.—"Effect of Ultrasonics on Electrode Processes" by A. L. Ferguson, L. O. Case, F. A. Reiss, and S. H. Dreisbach, Department of Chemistry, University of Michigan, Ann Arbor, Mich.

10:40 A.M.—"Effects of Ultrasonic Waves on Concentration Gradients at Electrodes" by Robert Penn, Ernest Yeager, and Frank Hovorka, Department of Chemistry, Western Reserve University, Cleveland, Ohio.

11:05 A.M.—"Hydrogen Overvoltage in Phosphate and Ammonium Buffers" by William Van Dusen, Jr., Alma Elizabeth Chick, and Andre J. de-Bethune, Department of Chemistry, Boston College, Chestnut Hill, Mass.

11:30 A.M.—"Some Properties of Tin-II Sulfate Solutions and Their Role in Electrodeposition of Tin, III. Solutions with Tin-II Sulfate, Sulfuric Acid, and Addition Agents" by C. A. Discher, College of Pharmacy, Rutgers University, State University of New Jersey, Newark, N. J.

Enlarged Abstracts Booklet Published Again

The Electronics Division will again publish an "Enlarged Abstracts" booklet for the 1954 Spring Meeting of the Society at Chicago. The booklet will have 1000-word abstracts of most papers to be given before the Electronics Division in its symposia on *Instrumentation*, *Luminescence*, *Phosphor Screen Application*, *Rare Metals*, and *Semiconductors*.

Abstracts will contain pertinent information and experimental data given in the papers and will provide these details before publication, thus aiding workers in the field. The abstracts will be "printed but not published."

Enlarged abstracts booklets should be available about April 1; the price will be $2.00. Orders should be sent to: C. W. Jerome, Sylvania Electric Products Inc., 60 Boston Street, Salem, Massachusetts.

Nominations for Officers

Members of The Electrochemical Society have the privilege of suggesting to the Nominating Committee names of eligible candidates for officers of the Society. Such nominations should be submitted to the Secretary by April 15.

Suggestions for nominations should be confined to individuals who have been active in the affairs of the Society.

DIVISION NEWS

Electronics Division

The annual business meeting of the Electronics Division will be held at the Spring Meeting of the Society (May 2 to 6, 1954) in Chicago. The specific time and place is given in the last paragraph of this item.

During the year a merger of the Rare Metals Section with the Electrothermic Division was proposed. A mail ballot of the Division membership on the proposed merger and the necessary changes to the Division's bylaws was taken and at the end of the 3-month period prescribed by the bylaws, the vote stands at 88 in favor, 5 against. The favorable vote is in excess of the necessary two-thirds of those replying and, consequently, the merger is approved and the bylaws changed accordingly. The merger will take effect immediately following the meeting in Chicago.

A survey to determine the fields of interest of the membership elicited 129 replies. The breakdown of the replies by symposia was: Rare Metals—53; Instrumentation—51; Luminescence—69; Screen Application—49; Semiconductors—69.

The Nominating Committee (J. R. Musgrave, Chairman, E. G. Widell, and H. R. Harner) has selected the following nominees for officers during the 1954–55 term:

General Chairman—A. L. Smith, RCA Victor Division, Lancaster, Pa.

Group Chairman—H. Bandes, Sylvania Electric Products Inc., Bayside, N. Y.

Group Chairman (General Electronics)—A. E. Middleton, P. R. Mallory and Company, Indianapolis, Ind.

The term of Secretary-Treasurer (C. W. Jerome) has one more year to run. All nominees have given assurance of their willingness to serve.

The bylaws of the Division provide that additional nominations may be made by petition signed by 5 members of the Division. Such petitions must be in the hands of the Nominating Committee Chairman before the election and

the nominees must give assurance of their willingness to serve.

The election will be held at the business meeting of the Division on Wednesday, May 5, at 12:30 P.M. in Parlor D at the LaSalle Hotel, Chicago.

C. W. JEROME, *Secretary-Treasurer*

Industrial Electrolytic Division

The Industrial Electrolytic Division announces an election of officers and consideration of changes in its Bylaws as to terms of offices and publication of notices to conform to the recommendations of the Board of Directors at the Luncheon Meeting, May 3, 1954, at 12:30 P.M. in the Chicago Room of the LaSalle Hotel.

SECTION NEWS

Chicago Section

The speaker for the January 8th meeting of the Chicago Section was Dr. W. S. Herbert, Technical Director, Ray-O-Vac Company, Madison, Wisconsin. He spoke on "Miniature Alkaline Dry Cells," a recent development of his company.

W. S. HERBERT

The adaptation of the system MnO_2-alkali-Zn to miniaturized cells was described in detail and was supplemented by a very effective exhibit of the several cell sizes manufactured, together with the physical and chemical characteristics of each.

A particularly intriguing feature of the new cells is their "bottle-cap" type construction. Two end plates which resemble tiny "crown" caps are snapped over opposite ends of a short plastic cylinder to form a wafer-type cell. The precision with which the components are manufactured makes it possible to stack the cells in the form of cylindrical batteries with little variation in over-all dimensions.

Dr. Herbert reported that the alkaline type cells yield 30 to 50% more capacity than Leclanché cells for light and medium rates of drain, and up to 100% more on heavy drains. The cells have high efficiency and very good space utilization.

HOWARD T. FRANCIS, *Chairman*

Cleveland Section

The February meeting of the Cleveland Section was held on Tuesday, February 9th, at the Cleveland Engineering Society. Dr. A. G. Winger of the Rohm and Haas Company, Philadelphia, spoke on "Ion Exchange Membranes."

Dr. Winger discussed the nature and properties of these membranes in terms of thermodynamic and electrochemical relationships. He pointed out that ions are not excluded, but that the transport of anions or cations is reduced. The ion-solvent interaction and consequent solvent transport was discussed. He also considered hydraulic and osmotic transport properties of the membranes.

Dr. Winger then showed how this knowledge can be applied to practical processes such as the multiple ion exchange electrodialysis cell and the recovery of iron and sulfuric acid from pickling liquors.

MERLE E. SIBERT, *Secretary*

Metropolitan New York Ladies' Night

The Ladies' Night Meeting of the New York Metropolitan Section will be held on May 12, 1954. Note the date! The Section has been fortunate to obtain Dr. Hubert N. Alyea of Princeton University, who will speak on "Atomic Energy: Weapon for Peace."

In his talk Dr. Alyea will trace the growth of ideas which led to the atomic bomb: of the vain attempts of the alchemists of the Middle Ages to transmute lead into gold; of Becquerl's accidental discovery of radioactivity, and of the Curies' isolation of radium; of Rutherford's interpretation of radioactive disintegration, and the nuclear atom, and of his achievement of artificial transmutation; how gradually we came to understand atomic structure, and isotopes, and how to smash atoms, and how, just before the beginning of World War II this was finally accomplished; and how man triumphantly tapped nuclear energy. Dr. Alyea will contrast the actions of ordinary high explosives with those of nuclear fission reactions and outline the work of the Manhatten Project in exploiting the fission reactions. The effects of an exploding atom bomb would have on persons a mile or two away, and protective measures against it will be outlined. The nature of the H-fusion bomb will be discussed briefly. A full treatment of the atomic pile, or nuclear reactor, will outline the various ways that new elements are produced in it, and some of the interesting new researches which are being accomplished with radioactive isotopes; the atomic pile as a source of energy . . . After this scientific review of the bombs will come a discussion of the likelihood of other nations using them, of the necessity for world-wide control of these devastating weapons, and of the peacetime blessing which may, instead, come from it.

Throughout the talk the various reactions will be illustrated with many chemical experiments and lecture demonstrations. Dr. Alyea has given this lecture, "Atomic Energy: Weapon for Peace" (with variations, as new material is declassified), over 700 times to over 600,000 people.

There will be door prizes for the ladies and very useful gifts for several lucky ticket holders.

Because of the extreme popularity of Dr. Alyea, it is imperative that all reservations are placed on or before April 21, 1954. Late reservations will be returned if the capacity of the meeting hall is exceeded. Send reservations to Dr. B. Agruss, National Lead Company Research Laboratories, 105 York Street, Brooklyn 1, New York. Please help your committee in planning a good time.

New York Metropolitan Section

At a meeting held at the Hotel Earle, Waverly Place, on January 13, 1954, Professor Andre J. deBethune of Boston College explained some of the fundamental concepts of the thermodynamics of irreversible processes. He pointed out that the basic relationships expressed the rate of creation of entropy by the process in terms of the work-producing ability of the system which is lost because of the irreversibility of the process. For example, in an electrolytic cell the rate of entropy production appears as the power lost in electrode polarization and I^2R loss in the electrolyte, diaphragms, etc.

A fundamental contribution, which has led to many valuable interrelationships in steady state processes involving flows of energy or material, has been the

The Problem of Correct Thermal Insulation of Bottom Linings of Aluminum Furnaces

J. Wleugel[1] and O. C. Böckman[2]

Introduction

Designers of aluminum furnaces are well aware that the thermal insulation of bottom linings for aluminum furnaces must be adjusted to the intended operating conditions of the furnaces, viz., current density of the anode, furnace voltage, and the distance between the anode and the metal bath acting as cathode. In this paper, a theoretical analysis of the problem is attempted, based on some measurements on operating furnaces and on thermochemical data for the reduction of alumina to aluminum metal.

Stating the Problem

The main characteristics of furnace operation are: (*a*) furnace voltage, in this paper designated E; (*b*) total direct current I, and the current density of the anode I/A; (*c*) distance between the anode and metal bath, designated d; (*d*) current efficiency, designated s; (*e*) specific energy consumption, expressed in kwhr/kg metal produced, designated r.

These five quantities are naturally interrelated and their relationships involve certain electrochemical and physical quantities: (*f*) heat of reaction, or change of enthalpy, of the cell reaction

$$Al_2O_3 + xC \rightarrow 2Al + \text{anode gases}$$

(*g*) change of free energy, or equivalently, the equilibrium decomposition voltage of Al_2O_3 under operating conditions; (*h*) effects of irreversibilities, or overvoltage; (*i*) different ohmic voltage drops: in the outer circuit (bus bars), in the anode and cathode, and in the electrolytic bath between the anode and cathode; (*j*) heat generation accompanying these different ohmic voltage drops; and (*k*) different heat losses of the furnace: heat conducted through the furnace bottom lining, through the anode, radiant heat losses from the bath especially when charging the alumina, and the heat content of anode gases and metal produced.

Two main aspects of the problem have to be discussed: (*A*) the energy balance of the furnace, and (*B*) actual voltage drops.

While a knowledge of the actual voltage drops is required to arrive at a true picture of the electrolytic process, the problem of correct heat insulation is solved mainly by proper application of the energy balance.

Heat losses represent a waste of energy, and any reduction in the heat losses per kg metal produced naturally turns out to be a gain in the energy efficiency of the process. By increasing the thermal insulation, heat losses may be reduced. However, the practical operation of the furnace imposes certain limitations as to the amount of insulation that may be applied.

A reduction in heat losses requires an equivalent reduction in heat generation in order to maintain the correct temperature of the bath. Generation of heat may be regulated mainly by regulating the distance between anode and cathode, and by regulating the total current, or, equivalently, the current density of the anode.

With a given current density, the effect of a reduction of heat generation by reducing the anode-cathode distance is complicated by a second phenomenon, viz., the current efficiency will simultaneously be reduced, especially at low values of anode-cathode distances. A reduction in current efficiency naturally will result in an increase in specific energy consumption.

Thus we find that two effects are opposed: when reducing the anode-cathode distance, the heat generated is reduced, which permits an increase in thermal insulation, but, at the same time, the current efficiency is reduced. It will be demonstrated that minimum specific energy consumption is obtained when these two opposing effects are properly balanced. Calculation of the conditions for the proper balancing of the two opposing effects provides means for the determination of the correct thermal insulation of aluminum furnaces.

In the discussions to follow, actual voltage drops will be calculated to arrive at a true picture of the process. Aspects of current efficiency have then to be considered, and lastly an energy balance will be set up to demonstrate the conditions for the minimum specific energy consumption.

Actual Voltage Drops

Actual voltage drops of a number of 33-kamp and 18-kamp furnaces have been determined in the following manner.

By constant current the anode is lowered successively until complete short-circuiting and the furnace voltage at different positions of the anode is noted. It is presumed that measurements are carried out so rapidly that the cell does not change its temperature during measurements. Measurements of different furnaces, all of them operating at the same current density, show a remarkable conformity. A good average of the measurements is given in Fig. 1.

It is seen that at first the furnace voltage decreases along a straight line as the anode is lowered. At a certain point, a sudden voltage drop of about 1.6 volts is observed. By further lowering the anode, a slight decrease in furnace voltage is noted until a constant value of about 1.4 volts is obtained.

This voltage characteristic of the furnace may be explained by assuming that direct contact between the anode and the metal bath at first is obtained in a single point, or at least in a restricted area. When this contact is established, electrolysis is interrupted and the voltage drop observed corresponds roughly to the decomposition voltage of the electrolysis. Complete short-circuiting is obtained when the total working surface of the anode is in direct contact with the metal bath, this condition being established by further lowering of the anode. The short-circuiting voltage of the furnace thus pro-

[1] A/S Norsk Aluminium Company, Oslo, Norway.
[2] Elektrokemisk A/S, Oslo, Norway.

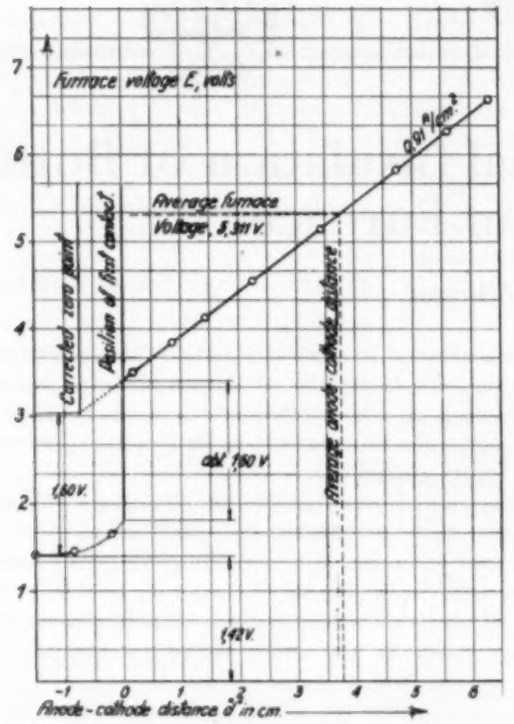


FIG. 1. Average experimental voltage characteristic of 33 kamp and 18 kamp aluminum furnaces.

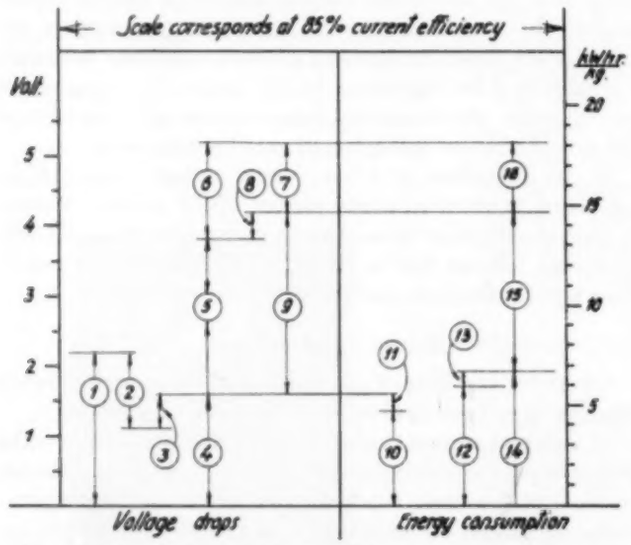


FIG. 2. Energetics of alumina reduction. 1—Decomposition voltage of alumina; 2—depolarizing effect of carbon; 3—overvoltage; 4—actual decomposition voltage; 5—voltage drop in bath; 6—voltage drop in current supply; 7—waste voltage drop in current supply; 8—useful voltage drop in current supply; 9—total useful voltage drop; 10—energy equivalent of decomposition voltage; 11—energy equivalent of current losses; 12—heat of reaction; 13—heat content of metal and gases; 14—total heat requirements of reaction; 15—useful heat generation; 16—waste heat generation in current supply.

vides a value for the combined voltage drops in anode and cathode, with their outer circuit for current supply. It is seen that this value is about 1.4 volts.

The measured value 1.6 volts for decomposition voltage checks well with measurements made by other investigators (1–3). It may be worth while to notice, however, that this value includes effects of irreversibilities, known as overvoltage. Calculations by the third law of thermodynamics (1, 4–7), as well as direct measurements in laboratory (1, 2, 6, 8, 9) have established the decomposition voltage of alumina at 1000°C to be about 2.2 volts. The depolarizing effect of the carbon anode may be calculated from the free energy of formation of CO and CO_2 to be about 1.1 volts (7). The equilibrium value of the decomposition voltage is then 2.2 − 1.1 = 1.1 volts, which, compared with the measured values of 1.6 volts, shows an overvoltage of about 0.5 volt.

Combining the short-circuiting voltage and the actual decomposition voltage, we get 1.4 + 1.6 = 3.0 volts, while the furnace voltage usually is 4.5–5.0 volts. The difference is made up of the voltage drop in the electrolytic bath between the anode and the metal bath acting as a cathode.

These voltage relationships are demonstrated in Fig. 2.

Current Efficiency

By the normal operation of aluminum furnaces aluminum is deposited with a current efficiency of 85–90%. No completely satisfactory theory has as yet been put forward to explain the mechanism of current losses. Grünert (10) and Pearson and Waddington (9) have given evidence for the view that current losses are caused by a simultaneous deposition of sodium metal. Possibly, monovalent aluminum may exist in the cryolite bath, and in some way play a part in current losses.

Fortunately, a knowledge of the mechanism of current losses is not needed for this analysis. Here it is enough to know the magnitude of current losses, and the variation of current losses with the distance between the anode and the aluminum bath acting as cathode.

Current losses also depend on the temperature and composition of the bath, and possibly on other factors. These factors do not affect our problem, as we postulate constant temperature and composition of the bath and consider other possible factors also to be unaltered.

In our calculations, current density is varied, and possibly variation in current density may affect the current efficiency of the electrolysis. At the moment, we have no data, however, to demonstrate this effect, and for this reason we consider current efficiency to be independent of current density. For our analysis, then, current efficiency may be considered to depend only on the anode-cathode distance.

It is well known that current efficiency decreases rapidly as this distance is lowered under a critical value of about 4 cm. Naturally, determination of current efficiency at different anode-cathode distance is difficult, as the measurements require operation of the furnace over a period of time sufficiently long, during which it is difficult to maintain constant operating conditions. The following figures have been obtained, however.

Distance anode-metal bath	Determined current efficiency	Values used for later calculations
cm	%	%
3	72–76	73
3.75		83.0
4	84–89	85
5	89–94	90
6	91–95	92
7	92–96	92.5

The distance between anode and metal bath given above is measured by lowering the anode until the first contact with metal bath is obtained. No zero point correction is introduced here (*see* Discussion of zero point correction).

As will be seen, the measured values allow for a fairly wide latitude. Accordingly, values selected for our calculations are somewhat uncertain, but, at the moment, we have no better values.

Energy Balance

When setting up an energy balance with the aim of providing means for calculating the conditions of minimum specific energy consumption, three main groups of energy dissipations must be distinguished.

Heat of Reaction

Energy consumed by the electrode reaction is equivalent to the heat of the net cell reaction

$$Al_2O_3 + xC \rightarrow 2Al + \text{anode gases}$$

The heat of reaction depends on the com,position of anode gases. With a gas composition of 65% CO_2 and 35% CO, the authors have calculated the heat of reaction at 1000°C to be 276.0 kcal/gram mole of alumina (7). This corresponds to 5.94 kwhr/kg Al. The sensible heat content of anode gases and of produced metal is a permanent loss and may logically be added to the heat of reaction. This addition amounts to 0.73 kwhr/kg Al under the assumed operating conditions, giving a total of 6.67 kwhr/kg Al.

For any furnace operating under these conditions, the energy consumed by the electrochemical reaction may be found by multiplying the number of kg metal produced with 6.67 kwhr/kg Al. To be correct, for furnaces operating under other conditions, viz., with other anode gas compositions, a slight correction of this value has to be introduced. This correction, however, is so small that in this paper it is neglected.

Actual decomposition voltage, multiplied by total direct current through the furnace, and by current efficiency, may be interpreted as the power input to the furnace directly converted to chemical energy. This power input may, by dividing with the metal production, be expressed as a specific energy consumption, and gives the figure 4.77 kwhr/kg Al. This figure, being less than the energy requirements of reaction, shows that a part of the energy requirements of the reaction must be supplied from other sources. Assuming that the power input associated with the current losses is fully recovered as useful heat and a current efficiency of 85%, which gives an additional energy supply, corresponding to 0.83 kwhr/kg, we get a total of 5.60 kwhr/kg. Even this figure is less than the energy requirements of the reaction. The difference, or 1.07 kwhr/kg, must then be supplied by heat generated by ohmic resistance, mainly in the bath.

This comparison of energy requirements of the reaction with actual decomposition voltage is demonstrated in Fig. 2.

Generation of "Useless Heat"

The power input to the furnace, not required for covering the heat of reaction and the sensible heat of anode gases and metal produced, is dissipated to the surroundings as heat losses. The power input, which corresponds to the voltage drops in the anode and cathode, in part contributes toward heating the electrolytic bath, and in part it is generated where it may be considered to be of no use. The short-circuiting voltage of the furnaces measured is 1.4 volts, which corresponds to the combined voltage drops of anode and cathode. Of this, we may estimate that 0.4 volt will contribute to the heating of the bath and 1.0 volt generates useless heat.

For measured furnaces we get the power input generating useless heat by multiplying this 1.0 volt by the total current.

Generation of "Useful Heat"

Total power input to the furnace may be calculated by multiplying the total furnace voltage by the total furnace current. By subtracting from the total power input the items calculated under heat of reaction and generation of useless heat, we get the heat generation necessary to maintain the correct temperature of the bath. This power input is dissipated as heat losses from the furnace bottom by heat conduction through the furnace lining and by radiant heat losses from the bath, especially during the charging of alumina.

The heat generation equivalent to this power input may be called the generation of "useful heat," as this heat generation is effectively utilized in keeping the bath at correct temperature.

It will be seen that we now have arrived at a quantity very important for our reasoning. By using data from furnaces in actual operation, the generation of useful heat may be calculated for this particular installation and operating conditions. We may then calculate the effect of changing the operating conditions, or of changing the heat insulation of the furnace bottom on the specific energy consumption.

Specific Energy Consumption

The following data serve as basis for our calculations.

A number of 33-kamp furnaces of the same design operating under the same conditions have for a long period of operation produced metal with a specific energy consumption of 19.1 kwhr/kg, as calculated from the weight of metal produced and the readings of the kwhr-meter of the series. Unfortunately, no kamp hr- or kvolt hr-meter were used, but frequent readings of the total series current and voltage established a reasonable value for the current efficiency to be 83.0%.

It may be shown that current efficiency s, specific energy consumption r, and furnace voltage E are related to each other by the equation

$$E = 0.3354 \cdot r \cdot s$$

when E and r are expressed in volts and kwhr/kg, respectively, and s is given as a fraction. The measured values given above then correspond to an average furnace voltage of 5.31 volts, which checks well with the average voltage of the series according to the frequent readings.

These figures, by the nature of their derivation, include the time when anode effects occur. During the anode effects the power input to the furnace is greatly increased, which, to a large extent, is converted into useful heat. For our purpose then it seems logical to include the time when anode affects occur, and the figure 5.31 volts will be used as an average furnace voltage.

According to the voltage characteristic of the furnace (Fig. 1), this average furnace voltage corresponds to an average distance between anode and cathode of 3.75 cm. This checks well with actual measurements of this distance for the furnaces in question as measured by lowering of the anode until the first contact with the metal bath.

It is not quite correct to use the average furnace voltage in combination with the voltage characteristic of Fig. 1 since the former includes anode effects and the latter is based on the normal operation of the furnaces. The main purpose of our investigation is, however, to demonstrate the effect of changing the operating conditions on specific energy consumption. It is felt that, although theoretically not correct, this simplification does not invalidate our conclusions as to the effects of changing the operating conditions. It must be stressed, however, that the actual figures given refer to this particular installation and the general methods of attendance used. For other installations and methods of attendance, other figures will result. It is thought, however, that the trend

of the figures may be more generally valid. To demonstrate this trend is the main purpose of our investigation.

We then arrive at the following fundamental data for the furnaces measured:

Furnace voltage, E	5.31 volts
Current, I	33.0 kamp
Current density, I/A	0.91 amp/cm²
Current efficiency, s	83.0 %
Specific energy consumption, r	19.1 kwhr/kg
Average anode-cathode distance, d	3.75 cm

By using these data and the furnace characteristic shown in Fig. 1, together with the relationship found between current efficiency and anode-cathode distance, we may construct lines showing the specific energy consumption at different total currents, or, equivalently, at different current densities. Thermal insulation is supposed to be unaltered. To maintain the correct temperature of the bath, the change in total current has to be compensated for by an equivalent change in anode-cathode distance, to give a constant generation of useful heat.

Suppose the thermal insulation is changed to give a different loss of heat at correct temperature of the bath. We may then repeat our calculations with the new value for the generation of useful heat.

In the calculations to follow, the 33-kamp furnaces, which have supplied the fundamental data, are supposed to operate at different operating conditions and with different thermal insulation of the furnace bottom. Similar calculations may be performed using data obtained from the operation of furnaces of other designs and of other sizes, generation of necessary useful heat being naturally dependent on furnace design and on furnace size as well as on the method of furnace attendance.

To carry out these calculations, we must first determine the generation of useful heat with the normal heat insulation of the furnace. This is done in the following manner:

Furnace current	= 33.0 kamp
Current efficiency	= 83.0 %
Metal production 23.0 kamp·0.83·0.3354 kg/kamp hr	= 9.1 kg/hr
Heat of reaction 9.18 kg/h·6.67 kwhr/kg	= 61.2 kw
"Useless heat" generation 1.00 volt·33.0 kamp	= 33.0 kw
By addition	94.1 kw
Furnace voltage	= 5.31 volt
Total power input 5.31 volts·33.0 kamp	= 175.2 kw
Useful heat generation by difference 175.2 − 94.1	= 81.1 kw
Specific energy consumption 175.2 kw/9.18 kg/h	= 19.1 kwhr/kg

Our calculations are carried out for five different cases:

(*A*) The insulation of the furnace bottom is reduced, necessitating 40% increase in the generation of useful heat, or a total generation of useful heat of 81.1·1.40 = 113.7 kw.

(*B*) 20% increase of said heat generation, or 81.1·1.20 = 97.4 kw.

(*C*) Normal insulation.

(*D*) 20% reduction of said heat generation by properly increased insulation, giving 81.1·0.80 = 64.9 kw.

(*E*) 40% reduction of said heat generation, giving 81.1·0.60 = 48.7 kw.

The voltage characteristic is naturally influenced by the current density of the electrolysis. The observed voltage characteristic, at a current density of 0.91 amp/cm², therefore has to be transformed to voltage characteristics at other current densities.

This transformation raises the problem of the choice of correct zero point for the distance between the anode and the metal bath. Obviously, the first point of contact is not the correct zero point because this point indicates the minimum distance which is less than the average distance.

A reasonable correction for the zero point may be obtained

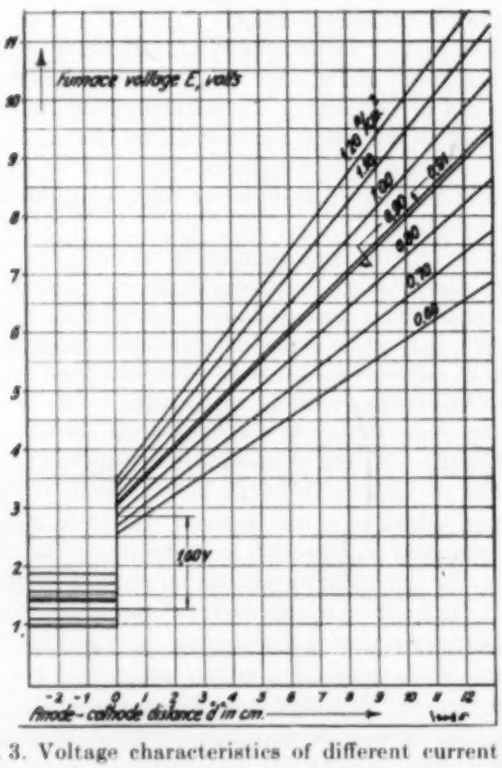


FIG. 3. Voltage characteristics of different current densities, corrected zero point.

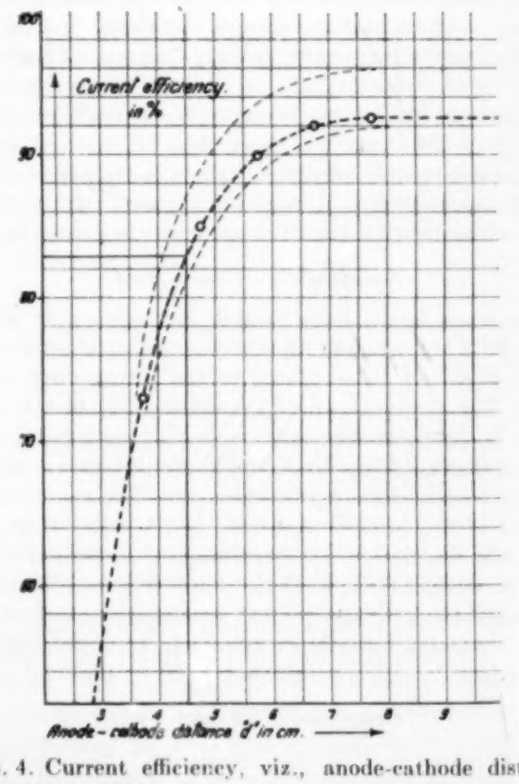


FIG. 4. Current efficiency, viz., anode-cathode distance, corrected zero point.

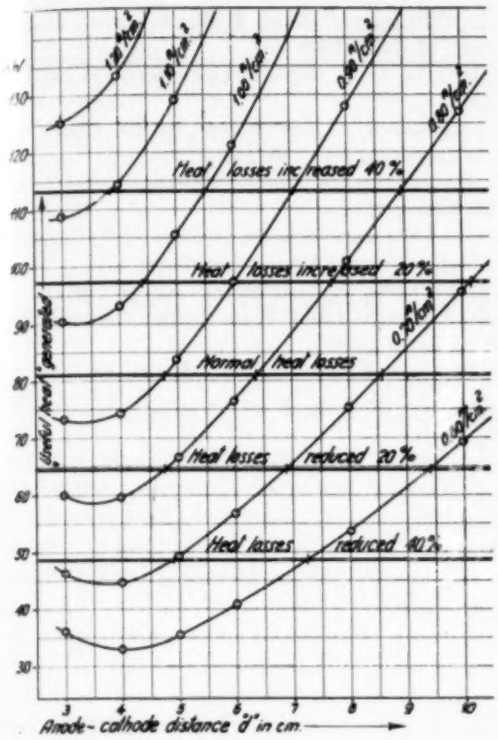

Heat losses increased 40 %
Heat losses increased 20 %
Normal heat losses
Heat losses reduced 20 %
Heat losses reduced 40 %
Anode-cathode distance d in cm

FIG. 5. Comparison of useful heat generated and heat losses from bottom lining.

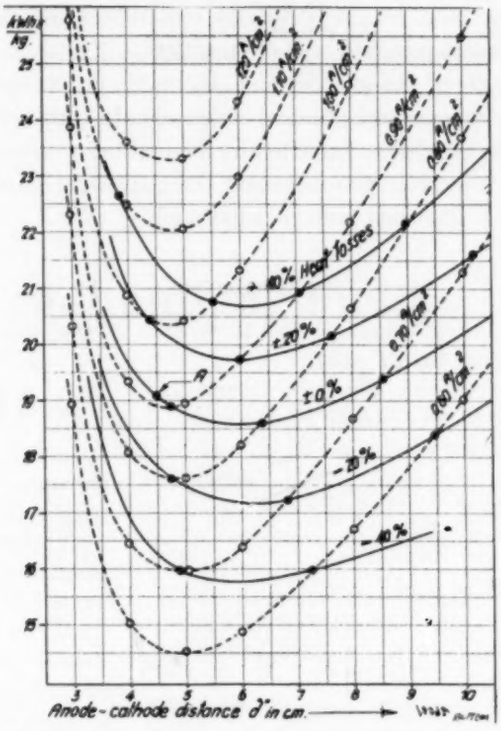


FIG. 6. Specific energy consumption at different current densities and different heat losses from furnace bottom.

in the following manner. The short-circuiting voltage may be considered as representing the voltage drops in the current supply under normal operating conditions. By adding the actual decomposition voltage, we arrive at 1.4 + 1.6 = 3.0 volts, which should be the furnace voltage at zero distance just before contact between anode and metal is obtained, assuming plane surfaces. By extrapolating the straight line of the voltage characteristic (Fig. 1) down to 3.0 volts, we arrive at a zero point correction of 0.75 cm. This correction is applied in all the later calculations.

The voltage characteristics at different current densities are given in Fig. 3. It may be seen from this figure that the short-circuiting voltage too is influenced by a change in current density. It is assumed that a constant proportion of the short-circuiting voltage is contributing to the generation of useful heat.

The current efficiency at different distances between the anode and metal bath with zero point correction introduced is given diagrammatically in Fig. 4.

By repeating the calculation of useful heat generation, assuming different current densities and different anode-cathode distances, we arrive at Fig. 5. From this graph, the correct anode-cathode distance may be found for different values of useful heat generation, corresponding to different thermal insulations of the furnace.

In this manner, an energy balance is set up for every hypothetical operation of the furnace indicated by the circles of Fig. 5. For the same hypothetical operating conditions, the specific energy consumption is calculated as given by the open circles in Fig. 6. The dotted lines indicate the current densities.

For each current density and furnace insulation (Fig. 5) the correct anode-cathode distance giving the correct generation of useful heat is noted and these values are introduced into Fig. 6, black circles. The circles representing the same furnace insulation are connected by fully drawn lines. These lines then represent the actually possible operating conditions of the furnace without altering the insulation.

The operating conditions of the furnaces that have provided the fundamental data are represented in Fig. 6 by the black circle marked A.

Discussion

From Fig. 6 it may be seen how the two opposing effects act. At small distances between the anode and the metal bath the specific energy consumption increases rapidly with a decrease in this distance. This effect is caused by the rapid decrease in current efficiency with a decrease in the anode-cathode distance at low values of this distance.

On the other hand, specific energy consumption increases but slowly with an increase in the anode-cathode distance above 6–7 cm, at constant insulation.

It may be seen further that an increase or a decrease in the amount of insulation applied imposes a change in operating conditions with accompanying changes in specific energy consumption. An increase in furnace insulation generally tends to reduce specific energy consumption. This increase in furnace insulation has to be compensated for by a decrease in anode-cathode distance or in current density. If the anode-cathode distance, however, turns out to be small, the increased insulation may result in an increase in specific energy consumption, as indicated by the left side of Fig. 6. This fact points to the danger of overinsulating the furnaces.

For a given installation, a change in current density results in a change in metal production. When considering the application of the relationship given in Fig. 6 to an installation actually operating, the problem of total metal production must be paid due attention.

When planning new installations, however, the relationships given may serve as a guide in the choice of proper operating data. With a given total metal production, the choice of current density will influence the linear dimensions of the furnaces, and consequently the installation costs. A

balance must here be struck on economic considerations of installation cost, viz., cost of operation.

Results of this analysis may, naturally, be anticipated by common sense and practical experience. It is thought, however, to be of some value to give a quantitative evaluation of the relationships to supplement the qualitative reasoning of common sense and practical experience.

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Current Affairs

News Notes in the Electrochemical Field

Gordon Research Conferences, August 16–20

The Gordon Research Conferences, sponsored by the American Association for the Advancement of Science, for 1954 will be held from August 16–20 at New Hampton School, New Hampton, New Hampshire.

The Gordon Research Conferences were established to stimulate research in universities, research foundations, and industrial laboratories. This purpose is achieved by an informal type of meeting consisting of the scheduled lectures and free discussion groups. Sufficient time is available to stimulate informal discussions among the members of a Conference. Meetings are held in the morning and in the evening, Monday through Friday, with the exception of Friday evening. Afternoons are available for recreation, reading, resting, or participation in discussion groups as the individual desires.

The purpose of the program is not to review the known fields of chemistry, but primarily to bring experts up to date as to the latest developments, analyze the significance of these developments, and to provoke suggestions as to underlying theories and profitable methods of approach for making new progress. In order to protect individual rights and to promote discussion, it is an established rule of each Conference that all information presented is not to be used without specific authorization of the individual making the contribution, whether in formal presentation or in discussion. No publications are prepared as emanating from the Conferences.

The morning sessions, Monday through Friday, are scheduled from 9:00 A.M. to 12:00 Noon, Eastern Daylight Saving Time. The second session of each day is held in the evening from 7:30 to 10:00 P.M., Monday through Thursday. There are no Friday evening meetings.

Individuals interested in attending the Conference are requested to send applications to the Director. Each applicant must state the institution or company with which he is connected and the type of work in which he is most interested. Attendance at each Conference is limited to 100. Communications should be addressed to W. George Parks, Director, Department of Chemistry, University of Rhode Island, Kingston, Rhode Island. From June 15 to September 1, 1954, mail should be addressed to Colby Junior College, New London, New Hampshire.

Shown below are the programs for the 1954 Conference on the Chemistry and Physics of Metals.

Chemistry and Physics of Metals

G. J. Dienes, *Chairman*
J. C. Fisher, *Vice Chairman*

Mechanical Properties of Metals

Monday, August 16

H. Brooks—Electronic Theory of Cohesion and Elastic Constants.
C. Wert—Anelasticity of Metals.
J. R. Low—Microstructure and Fracture.
E. W. Hart—Role of Dislocations in Plastic Deformation.
B. E. Warren—X-Ray Measurements of Cold Work Distortion.
M. Bever—Stored Energy.

Tuesday, August 17

E. Parker—Work Hardening and Substructure.
J. Washburn—Work Hardening and Substructure.
R. W. Cahn—Mechanical Twinning.
H. B. Huntington—Variation of Elastic Constants with Temperature and Pressure.
R. W. Powers—Internal Friction due to Impurities.

Wednesday, August 18

E. Montroll—Frequency Spectrum of Vibrations of Crystal Lattices.
A. Nowick—Internal Friction Effects Produced by Dislocations.
L. Zernow—Plastic Deformation and Fracture at Very High Strain Rates.
T. H. Blewitt and R. R. Coltman—The Deformation of Copper Single Crystals.
C. E. Dixon—Low Temperature Irradiation and Plastic Deformation.
R. H. Pry—Electrical Resistivity.

Thursday, August 19

J. H. Koehler—On the Production of Vacancies and Interstitials during Cold Work.
J. J. Gilman—Cooperative Dislocation Motion.
F. C. Frank—Dislocation in Real Crystals.
K. Lucke—Strain Hardening in Face Centered Cubic Metals.

Friday, August 20

R. Truell—The Use of Ultrasonics in the Study of Solid State Problems.
T. Vreeland, D. S. Wood, and D. S. Clark—Delay Time in Yielding.
R. Smoluchowski—Structure of Grain Boundaries.

Annual Meeting of Engineering Educators

Over 1,500 engineering educators will attend the Annual Meeting of the American Society for Engineering Education on June 14–18 at the University of Illinois, Urbana, Ill. Educators and distinguished engineers from other countries who are visiting in the United States are cordially invited to attend this meeting.

The meetings will include conferences sponsored by the Engineering College Administrative Council and the Engineering College Research Council, which are two component organizations of the ASEE. The theme of the conference this year, "Evaluation of Engineering Education," will feature a thorough analysis of all phases of engineering education. This will conclude

a two-year study on Evaluation of Engineering Education undertaken by the society.

The Engineering College Research Council and Engineering College Administrative Council will hold a joint dinner to commemorate the 50th Anniversary of the founding of Engineering Experiment Stations in engineering colleges, a movement which has contributed very substantially to research progress in this country. The speaker at this dinner will be Dr. Lee DuBridge, President of California Institute of Technology.

There will be over 100 individual conference programs arranged by the numerous divisions, committees, and councils of the society.

Foreign guests who wish to attend the Conference should write to Professor Robert K. Newton, ASEE Housing Chairman, University of Illinois, Urbana, Ill., for information and reservations.

Pennsalt Chemicals Creates New Operating Divisions

To provide more logical product grouping, better customer service, and a suitable pattern of organization for expected future growth, the Pennsylvania Salt Manufacturing Company will establish two new operating divisions, it was announced by President George B. Beitzel.

These new components—the Industrial Chemicals and Chemical Specialties Divisions—will function as complete operating units responsible for both the manufacture and sale of their respective products. Other units already operating on this basis are the Pennsylvania Salt Manufacturing Company of Washington, Sharples Chemicals Inc., and Pennsalt International Corporation.

The change-over will be made gradually during a period of approximately a year, and most changes will be at top and middle management levels.

New G. E. Wire Probe

A tiny platinum wire one-thirtieth as thick as a human hair is being used at the General Electric Company's Research Laboratory in Schenectady, N. Y., to detect thin films which interrupt electrical contacts between metal surfaces.

Formed into a loop by scientists at the laboratory, the thin wire can be employed to detect finger prints and other films built up by oxidation or tarnishing. Even invisible films can frequently be detected.

When compressed against a surface, the resilient platinum probe ferrets out films on the most highly buffed and machined surfaces. Measurement of the pressure exerted with a micrometer suggests the type of film present and its electrical strength.

Developed by Robert H. Savage and Dr. Donald G. Flom, the wire probe has been used at times to replace difficult chemical means for analyzing such films. These chemical techniques, it was pointed out, often destroy or damage the surface, while the delicate probe does not affect it.

Michigan State Alumni to Meet

The Michigan State College alumni in the electroplating field are planning a breakfast reunion in connection with the annual meeting of the American Electroplaters' Society, to be held in New York City during July. All former students of Professor D. T. Ewing are invited, together with other alumni who are interested in the electrodeposition of metals. Announcements will be sent to all Michigan State alumni known to be in this field, but since such lists are necessarily incomplete, requests for further notification should be sent in promptly. Reunion plans are being handled by C. Fred Gurnham, Head of the Department of Chemical Engineering, Michigan State College, East Lansing, Mich.

Ionic Pump Developed by G. E.

Two General Electric scientists have built a simple experimental air pump with no moving parts, which can produce a vacuum as high as one billionth of normal atmospheric pressure, similar to that in x-ray tubes and TV picture tubes.

According to Dr. A. M. Gurewitsch and Dr. W. F. Westendorp, of the company's Research Laboratory, Schenectady, N. Y., the device, known as an ionic pump, may eventually simplify exhaustion of radio tubes and other widely-used vacuum tubes in the process of manufacture.

Pumps presently used for the purpose involve streams of oil or mercury vapor, which are not required in the new device.

Symposium on Electrochemical Processes and Their Applications to Indian Industry

A symposium on "Electrochemical Processes and Their Applications to Indian Industry" was held at Karaikudi on March 27 and 28 under the auspices of the Central Electrochemical Research Institute, Karaikudi. It was divided into four sections: (*a*) electrometallurgy and electrothermal processes, (*b*) electrolytic processes, inorganic and organic, (*c*) batteries, electrodeposition and electropolishing, (*d*) miscellaneous. Nearly 60 papers were presented, covering all the branches of electrochemistry. The members of the India Section of The Electrochemical Society contributed 25 papers; the authors were: A. Joga Rao, S. L. Chawla, H. V. K. Udupa, N. Subramanian, K. Seshadri, V. Aravamuthan, T. Banerjee, T. L. Rama Char, and B. A. Shenoy. Professor M. S. Thacker, Chairman of the India Section, participated in the proceedings.

There was a good gathering drawn from research laboratories, electrochemical industries, and government establishments all over India. The discussions that followed the papers were extremely interesting. The program was rounded off with social functions.

T. L. Rama Char,
Regional Editor, India

SECTION NEWS

Chicago Section

The Chicago Section held its monthly meeting at the Chicago Engineers Club on Friday, February 5. Dr. Malcolm Dole spoke to the Section on the effects of reactor irradiation on the chemical and physical properties of polyethylene. Despite the prevailing cold weather there was a good turnout of local electrochemists.

Dr. Dole described the experiments he had performed, briefly discussed the equipment involved, and elaborated on the results obtained and the theories involved. In general, reactor irradiation was found to break carbon to hydrogen and carbon to carbon bonds, and to result in a certain amount of increased polymerization and chemical unsaturation of the plastic.

Samples of polyethylene were irradiated in the Argonne National Laboratory CP-3′ reactor. Chemical and

physical measurements were made before and after irradiation. Products given off due to irradiation bond rupture included hydrogen and short chain saturated and unsaturated hydrocarbons. The increased chemical unsaturation of polyethylene caused by irradiation was measured by determining the amount of hydrogen which was evolved and by measuring the amount of unsaturation before and after irradiation by the bromine addition reaction.

In the discussion which followed, it was pointed out by Dr. Dole that experimental evidence indicated that a majority of the bonds which were broken were located in the side chains. This lead to increased linkages through these short chains, and the development of a higher molecular weight plastic. It was further pointed out that increased polymerization caused increased viscosity and increased the softening and melting point temperatures.

In conclusion, Dr. Dole answered questions raised from the floor and discussed at greater length several theories he had developed relating to the chemical reactions of polyethylene taking place under irradiation.

A. H. Roebuck, *Secretary*

Cleveland Section

The Cleveland Section met on April 13 at the Cleveland Engineering Society. Following the dinner, Mr. Quilan, a representative of the Cleveland Technical Societies Council, spoke on behalf of the proposed new Cleveland Engineering Center.

Dr. L. W. Niedrach of the Knolls Atomic Power Laboratory, Schenectady, was guest speaker. His topic was "Atomic Power, Present and Future." Existing nuclear reactors were described and a comparison made between the homogeneous and heterogeneous types. Dr. Niedrach discussed development work which will be required to achieve an economically feasible reactor, including improvements in design and operation, chemical processing of materials, and utilization of by-products. Atomic energy was considered relative to its position among the world's energy resources. Finally, an interesting comparison was given between a nuclear reactor power plant and a conventional coal powered generating station.

The annual Cleveland Section Award to an outstanding student of the colleges in the Cleveland area was presented at this meeting. This year the award went to Warren Krause of Cleveland, a student at Western Reserve University.

Merle E. Sibert, *Secretary*

New York Metropolitan Section

The guest speaker for the April 7 meeting of the New York Metropolitan Section was Mr. George F. Weaton, whose subject was "Electrothermic Zinc." The history of electrothermic zinc smelting was reviewed and the process in use at the smelter of the St. Joseph Lead Company at Josephtown, Pa., described.

In 1885 the Cowles Brothers in England attempted to smelt zinc in a small horizontal retort about 10 in. in diameter and 5 ft long, in which the charge of zinc-bearing material mixed with carbon was used as a resistor to supply heat for the reduction. Development work was started in 1893 in Sweden, resulting in a commercial plant built in 1903. By 1918 there were 22 furnaces of 500 hp each in operation. It appears that the major fault with this installation was in the method used to condense the zinc vapors. The best results showed these furnaces using 2.95 kwhr/lb of zinc. Many other people experimented with electric furnaces for smelting zinc and the inefficiency of the available condensers was an important cause of failure.

Development work on the electrothermic smelting of zinc was started by the St. Joseph Lead Company in 1926. Mr. E. C. Gaskill brought to the company a very small model and soon built an 18-in. diameter unit. This furnace was operated for several short periods, and while it was not a successful unit it encouraged the company to build a furnace 48 in. in diameter. The adoption of a rotary table at the bottom solved the problem of disposing of the residue. The top section of the furnace, originally used as a preheater, caused trouble and a separate heater was designed. The furnace was built originally with six electrodes at top and bottom, but these were soon reduced to three. The furnace was later enlarged to 57 in. in diameter. During this time the furnace had been operated to produce zinc oxide.

In the reduction of zinc oxide by carbon, the temperature must reach about 1050°C before the rate of reaction is satisfactory for commercial operation. The vapors produced consist of equal volumes of zinc vapor and carbon monoxide. Zinc vapor has a great affinity for oxygen, so condensation of metal must be conducted in an atmosphere devoid of oxidizing agents. The further development of the electric furnace depended on the development of an efficient condenser capable of handling the large volume of vapors produced. The vacuum type condenser which was developed by the company made today's large scale production of electrothermic zinc possible.

After the formal talk, slides showing views of the plant at Josephtown were shown and discussed. A film showing the mining and concentration of the ore was also presented.

Kenneth B. McCain,
Secretary-Treasurer

Washington-Baltimore Section

At the March 18, 1954 meeting of the Washington-Baltimore Section, Dr. Bernard Rubin of the National Bureau of Standards gave an excellent talk on "Galvanic Cells with Fused Salts."

The development of galvanic cells using solid-molten electrolytes was traced from the fuel cell of Jablochoff in 1877 to the present day. Two advantages of these cells were cited: (*a*) their extended shelf-life while the electrolyte is in the solid state, (*b*) the compactness and ease of handling as a result of the absence of water. The cell $Mg/NaOH/MnO_2$, C was discussed with particular emphasis on the nature of the electrolyte and the nature of the cathode material. A review of the thermodynamic data necessary for calculating emf's of reversible thermal cells was given, and a new electrochemical series for the elements was derived. Several notable exceptions to the aqueous series were pointed out. With the newer sources of heat energy now available, thermal cells show great promise as sources of electrical energy.

Fielding Ogburn, *Secretary*

Dr. J. O'M. Bockris gave a highly stimulating lecture entitled "Research Vistas in Electrochemistry" at the April 15 meeting of the Washington-Baltimore Section. Dr. Bockris observed that after a period of reduced activity in electrochemical research the field has now become more active again. He ascribed the loss of interest which occurred during the 30's and early 40's to discouragement resulting from the inapplicability of Debye-Huckel Theory

and "Nernstist" thermodynamics to many important electrochemical processes. The application of the kinetic-molecular approach, as typified by the Eyring absolute rate theory, to electrochemical problems has proved fruitful and provided a new impetus to research in electrochemistry.

Examples of how the kinetic-molecular approach has resulted in significant advances in our understanding of hydrogen overvoltage and of the structure of molten silicates were cited.

Dr. Bockris indicated his belief that the kinetic-molecular approach to the electrochemistry of fused salt, non-aqueous systems, and concentrated aqueous solutions will yield new knowledge in the field of solution theory and structure of ionic liquids.

At the same meeting, the following officers were elected to serve for the 1954–1955 term:

Chairman—Fielding Ogburn, National Bureau of Standards, Washington, D. C.

Vice-Chairman—D. T. Ferrell, Jr., Naval Ordnance Laboratory, Washington, D. C.

Secretary-Treasurer—Jeanne B. Burbank, Naval Research Laboratory, Washington, D. C.

FIELDING OGBURN, *Secretary*

PERSONALS

H. M. FISHER, technical supervisor of the Pennsylvania Salt Manufacturing Company's Natrona, Pa., plant, has been named technical assistant to the manager of Pennsalt's Calvert Works, Calvert City, Ky.

J. S. MACNAIRN, formerly research associate at Massachusetts Institute of Technology, Cambridge, Mass., has joined the engineering staff of the Chrysler Corporation, Detroit, Mich.

ROBERT A. STAUFFER, vice-president and director of research of the National Research Corporation, Cambridge, Mass., has been elected to the Board of Directors of the company. He is also vice-president and a director of the Vacuum Metals Corporation, jointly owned by the Crucible Steel Company of America and the National Research Corporation.

CHRISTOPHER L. WILSON recently became director of research at the Hudson Foam Plastics Corporation, Yonkers, N. Y. Formerly a professor in the Department of Chemistry at Ohio State University, Columbus, Dr. Wilson still retains a part-time position there.

VERNON A. LAMB, assistant chief of the Electrodeposition Section, National Bureau of Standards, Washington, D. C., has received the Department of Commerce Silver Medal for Meritorious Service. The award was made for outstanding contributions and distinguished leadership in development engineering in the field of electrodeposition.

EMILIO JIMENO of the University of Madrid, Spain, has recently been awarded the title of Doctor in Engineering "honoris causa" by the Engineering College of Hannover, Germany, for his contributions in chemistry, metallurgy, and corrosion.

GEORGE F. HERRMANN is now associated with S. W. Farber, Inc., Bronx, N. Y. In his position as chemical engineer he is responsible for all chemical operations involved in the manufacture of "Farberware" stainless steel aluminum clad kitchen utensils, aluminum giftware, and brass holloware with chrome on nickel plate. Mr. Herrmann was previously chemical engineer at Ronson Art Metal Works, Inc., Newark, N. J.

CHARLES A. THOMAS AND CARROLL A. HOCHWALT, president and vice-president, respectively, of the Monsanto Chemical Company, St. Louis, Mo., were among officers re-elected to the Board of Directors of the company for the coming year.

HOWARD ADLER, chemical director at Victor Chemical Works, Chicago, Ill., has been elected to the company's newly-created position of vice-president in charge of chemical research.

CLIFFORD A. HAMPEL, chemical engineer, Homewood, Ill., and president of the Chicago Technical Societies Council, is a member of the commission named by Chicago's Mayor to nominate appointees for membership on the Chicago Board of Education.

KARL M. LEUTE

Karl M. Leute, President of the Lithium Corporation of America, Inc., and also President of the Manganese Chemicals Corporation, both of Minneapolis, Minn., died on March 24, 1954, in Phoenix, Ariz.

Mr. Leute was born in Duluth, Minn., and was active in that city, as well as Detroit, Minneapolis, and Knoxville, in various enterprises. In 1937 he founded the Electro Manganese Corporation and erected the first successful commercial plant for the production of electrolytic manganese. The Metalloy Corporation, which was later to become the Lithium Corporation of America, Inc., was founded by Mr. Leute in 1942. In the ensuing 12 years he built the company into the leading factor in the lithium field. He formed the Manganese Chemicals Corporation in 1950 to produce manganese compounds from low-grade ores in Minnesota. This company had recently erected a plant at Riverton, Minn.

Less than two weeks prior to his death, Mr. Leute had announced plans on the part of Lithium Corporation to erect a $7,000,000 plant for the expanded production of Lithium products at Bessemer City, N. C. Following completion of the arrangements for this project, Mr. Leute had gone to Phoenix for a vacation.

It has been announced that operations of the Lithium Corporation will continue unchanged. The Board of Directors of the company have appointed Herbert W. Rogers, Secretary of the corporation, to assume the duties of President of Lithium Corporation of America, Inc.

Mr. Leute became a member of The Electrochemical Society in 1940. He also held memberships in various technical societies, including The American Chemical Society, The American Institute of Mining & Metallurgical Engineers, and the American Society for Metals.

He is survived by his wife, Mayme, a daughter, Mrs. Rome Riebeth, and two grandchildren.

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LETTER TO THE EDITOR

Journal Advertising

Dear Sir:

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There is nothing improper about having advertising in a technical journal, providing it does not interfere with the proper function of the publication. This function is to distribute and preserve scientific information. It is accomplished best if adequate funds are available to provide space for prompt publication of all worthwhile manuscripts.

Advertising does not interfere with the function of the JOURNAL as long as skillful editing separates technical writing and advertising in such a way that continuity is preserved, and so that binding of the permanent, technical record can easily be made independent of ephemeral matter. It would be objectionable, for example, to have advertising intercalated with technical writing; it is not objectionable, however, to have end sections or central sections devoted to advertising.

Let us welcome the advertisers. They are also members of our Society. Their company's advertising itself is literature, which to be effective in its own purpose must be at least of temporary interest to the reader. Let us do all other things which can insure a permanent, adequate, well-edited, dignified, and solvent journal.

J. F. GALL
Pennsylvania Salt Manufacturing Co., Philadelphia, Pa.

MEETINGS OF OTHER ORGANIZATIONS

AMERICAN SOCIETY FOR TESTING MATERIALS, 57th Annual Meeting, Hotel Sherman, Chicago, June 13–18, will include the 11th Exhibit of Testing and Scientific Apparatus and Laboratory Supplies, and the 9th Photographic Exhibit with the theme Materials, Testing, and Research.

L'ALUMINIUM FRANCAIS and LA SOCIETE CHIMIQUE DE FRANCE, Scientific Congress and Exhibition, Paris, June 14–19, celebrating centenary of the first production of industrial aluminum in France by Henry Sainte-Claire Deville. Program and other relevant information available from the Secretary, L'Aluminium Francais, 23 Rue Balzac, Paris (8e), France.

CHEMICAL INSTITUTE OF CANADA, 37th Annual Conference and Exhibition, Royal York Hotel, Toronto, June 21–23; 2nd Western Regional Conference, Vancouver, B. C., Sept. 10–11.

INSTRUMENT SOCIETY OF AMERICA, third annual Analytical Instrument Clinic to be held in conjunction with the First International Instrument Congress and Exposition, Philadelphia, Sept. 13–15. Advance registration required. For registration forms and further information write Dr. Axel H. Peterson, Mellon Institute, 4400 Fifth Ave., Pittsburgh 13, Pa.

FIRST INTERNATIONAL INSTRUMENT CONGRESS AND EXPOSITION, Philadelphia, Sept. 13–24.

THIRD SALON DE LA CHIMIE ET DES MATIÈRES PLASTIQUES, Paris, Dec. 3–12.

BOOK REVIEWS

TEMPERATURE MEASUREMENT IN ENGINEERING, by H. Dean Baker, E. A. Ryder, and N. H. Baker, Vol. I. Published by John Wiley & Sons, Inc., New York, and Chapman and Hall Limited, London, 1953. 179 pages, $3.75.

The preface states "The object in this two-volume work is to provide in convenient non-mathematical form the information necessary to the engineer who wishes to measure temperature. An effort has been made to include all those specific details essential to actual execution, while refraining from encumbering the space with material of infrequent application or of the nature of background theory. . . . Volume I deals primarily with thermocouple technique. . . ."

The book gives many references to the literature, is well indexed, and contains many fine detailed drawings of practical thermocouple installations.

However, the reaction of this reviewer is generally unfavorable. The "how" is overemphasized relative to the "why." The first four chapters (33 pages) are intended as theory for both volumes, and are inadequate. More mathematics would strengthen the book without troubling any engineer. Students will learn little nor retain the various methods described in later chapters. British units are used throughout, rather than metric. Much of the text is excessively detailed. For example, in Chapter 9 (21 pages) dealing with drilling holes to insert thermocouples into samples, the following occurs:

"If a hole is drilled, the required depth of the hole is the distance, from the most accessible point on the surface from which the leads are to emerge, to the interior point at which temperature is to be measured. The diameter of the hole must be sufficient to accommodate the sensitive element and the leads.

"The larger the diameter of the hole, the greater will be the disturbance in temperature distribution within the body, because of the existence of the hole and of the thermocouple installation. Error in measurement is thereby greater for a larger diameter hole and less for a smaller diameter hole. The required diameter of hole is that which will just accommodate the installation. With thermocouples, the size of the sensitive element and leads, i.e., of the bead and lead wires, can be made very small by using small diameter wires."

Most of page 123 is occupied by a drawing of a hypodermic used to inject CCl_4 into a hole to wash out chips formed in drilling, and nearly all of page 126 by a description of method for removing broken drills. Very few engineers will need such discussion.

GEORGE E. MOORE

Correction

ROBERT D. NUTTING continues his association with E. I. du Pont de Nemours and Company, Inc., Newport, Del., as research supervisor in the Chemical Division of the Pigments Department.

SCHRADE F. RADTKE is director of the Metallurgical Research Laboratories of the Reynolds Metals Company, Richmond, Va.

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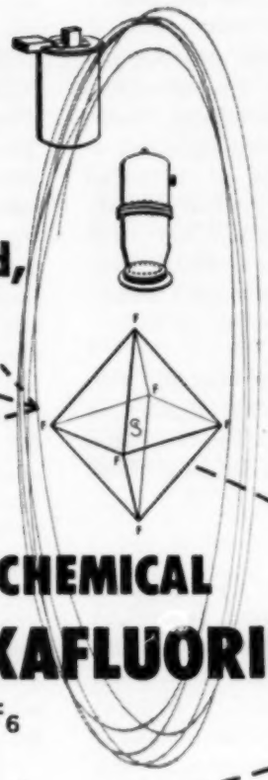

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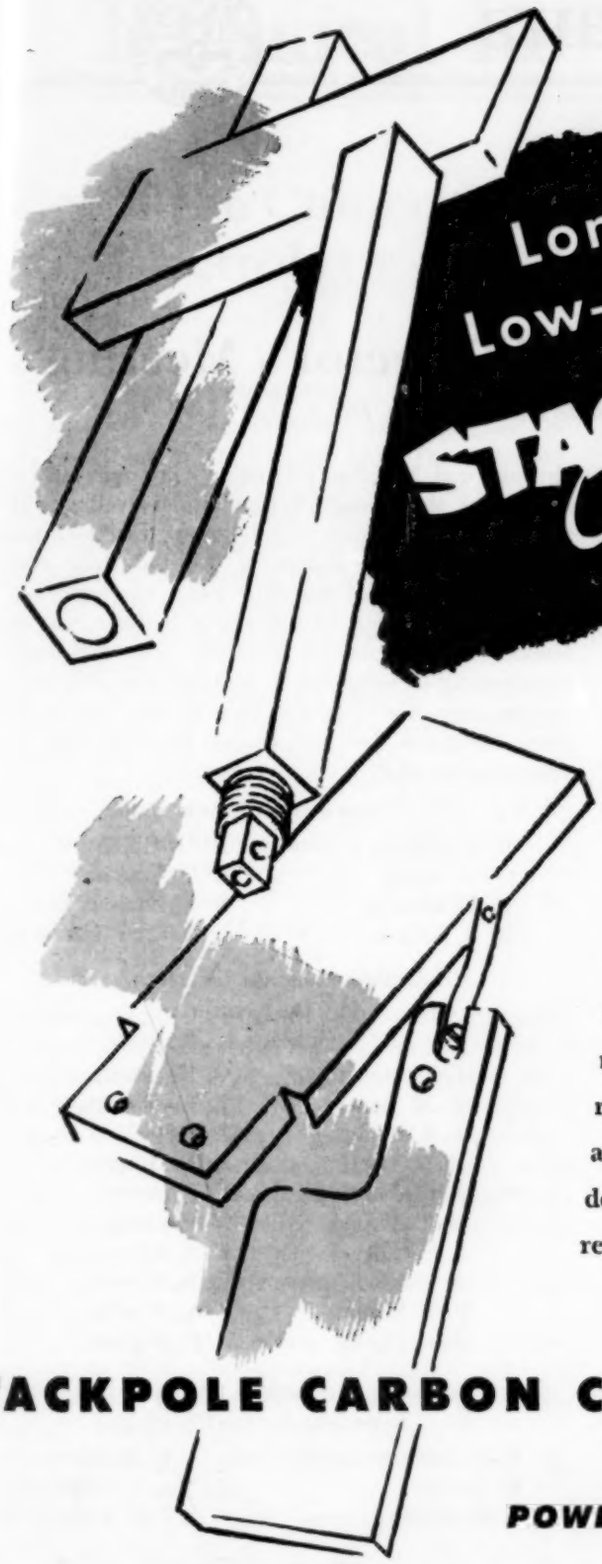
GENERAL CHEMISTRY, AN INTRODUCTION TO DESCRIPTIVE CHEMISTRY AND MODERN CHEMICAL THEORY, by Linus Pauling, 2nd ed. Published by W. H. Freeman and Co., San Francisco, 1953. xii + 710 pages, 193 illustrations. $6.00.

A reviewer of the first edition of this book (1947) said that the student who could "make the grade" in mastering its contents would really have something worth while; and one might almost wonder what would be left for him to learn in the field. There was, of course, much more material available, and some of it is found in this second edition; there are over 50% more square inches of print, on more and larger pages. The author estimates that the book contains about 10% more material than is needed in a one year college course. Most teachers (to say nothing of students) will think him much too optimistic.

The book can only be recommended as a text for the superior and serious student who has an excellent background in high school chemistry, physics, and mathematics. It is too bad that Professor Pauling did not drop any pretense of writing for the beginner, since so much elementary definition and detail is missing anyway. Written exclusively for the superior group with previous experience, the text could have been kept to a more reasonable length, the lack of logical presentation would not be so obvious, and the book could assume its true stature as an excellent text on a somewhat advanced level.

As in the first edition, there is no "historical approach" to chemical theory. Assuming somewhat more prior knowledge than just that "every boy knows about atoms," why not start with authentic, modern description of the atom and its constituent particles, the molecule, x-rays, crystals and crystallography, radioactivity, the nature of electricity, quantum theory? On the other hand, it seems difficult, illogical, and unnecessary to try to derive elementary chemical theory from the pertinent experiments of physics alone. Historically, the experiments were just not planned that way; they were designed with current chemical knowledge fully in mind. The suggestion of discrete electrical particles hinged on atomic theory, not the other way round. The first experiments on x-ray diffraction were a test of the nature of the rays rather than of the crystals. More modern and advanced chemical theory is, of course, completely interwoven with physical theory.



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Current Affairs

Highlights of the Board of Director's Meeting

(Held May 2, 1954, La Salle Hotel, Chicago, Ill.)

Present in person were: R. J. McKay, President; M. J. Udy, President-Elect; H. Thurnauer, Vice-President; R. M. Hunter and G. W. Heise, Past Presidents; J. C. Warner, Chairman of Ways and Means Committee; R. M. Burns, Chairman of Editorial Staff; F. A. Lowenheim, Chairman of Local Section Advisory Committee; Norman Hackerman, Technical Editor; R. H. Cherry, Chairman of Electronics Division; M. L. Holt, Chairman of Electrodeposition Division; F. W. Koerker, Chairman of Industrial Electrolytic Division; R. A. Ruscetta, Chairman of Electric Insulation Division; J. P. Fugassi, Chairman of Theoretical Division; I. E. Campbell, Chairman of Electrothermic Division; E. Willihnganz, Chairman of Battery Division; H. T. Francis, General Chairman of Chicago Meeting; H. B. Linford, Secretary; and R. G. Sterns, Managing Editor.

The minutes of the previous meeting were approved as distributed.

The financial status of the Society was discussed. From all appearances, the operations this year are well within the budget. The report on the Ten-Year Index venture was made by the Secretary, showing a net profit of $2871.02 with 24 copies still on hand to be sold. This money was transferred to the Publication Reserve with the understanding that the Publication Reserve shall be used in the future to underwrite Ten-Year Indexes, insuring their continued publication.

The Secretary reported that negotiations are now under way between John Wiley and Carl Hans Verlag of Munich to arrange for German translation of "Modern Electroplating."

A communication from Dr. Uhlig was read by the Secretary in which Dr. Uhlig requested that the Board consider giving the Pacific Northwest Section a sum of $50.00 to be used for a membership campaign. The Board approved this request.

The Secretary reported on estimated costs for preparation of program booklets. The Chicago program booklet of 100 pages cost us $978.00. An estimate from Edwards Bros. for a 96-page program booklet was $550.00, provided the manuscript was sent in typed, ready for photography. It was agreed that the photo-offset method should be tried for the program booklet preparation.

The report of the Ways and Means Committee was read. This Committee recommended that the Constitution, in its current form, be presented at the annual meeting for approval. This was passed (the revised Constitution is printed elsewhere in this copy of the Journal). Bylaw changes necessitated by the change in Constitution were presented and passed.

Dr. Ivor Campbell submitted the proposition that the name of the Electrothermic Division be changed to "Electrothermics and Metallurgy Division" in conformity with the request at the Executive Committee meeting with representatives of the Rare Metals group, Electrothermic Division, and a representative of the Industrial Electrolytic Division. The official change in name was approved.

At the conclusion of the year's business, the Secretary tendered his resignation, at which time the Board voted unanimously to reappoint H. B. Linford as Secretary for the coming year. The chair was then turned over to President-Elect Marvin J. Udy, who made the following committee appointments which were all approved:

Ways and Means Committee

R. J. McKay, *Chairman*	H. H. Uhlig
G. W. Heise	H. Thurnauer
R. M. Hunter	F. A. Lowenheim
R. A. Schaefer	L. O. Case (alternate)

Membership Committee (subject to revision by the Chairman)
L. I. Gilbertson, *Chairman*

J. E. Archer	G. H. Kissin
O. M. Arnold	F. W. Koerker
J. R. Bukey	J. A. Lee
H. R. Copson	J. R. Musgrave
John Currey	F. P. Peters
H. T. Francis	M. Sadowsky
J. F. Gall	E. A. Schumacher
A. Gunzenhauser	D. R. Turner
C. A. Hampel	R. A. Woofter
A. E. Hardy	E. B. Yeager

Sustaining Membership Committee (subject to revision by the Chairman)

F. A. Lowenheim, *Chairman*	L. M. Morse
H. Bandes	J. R. Musgrave
G. H. Kissin	J. C. Schumacher

Admissions Committee
L. Weisberg, *Chairman*
Herbert Bandes
L. I. Gilbertson

Publication Committee

R. M. Burns, *Chairman*	C. V. King
H. B. Linford	N. Hackerman

Acheson Award Committee

E. G. Enck, *Chairman*	W. Blum
S. Swann, Jr.	H. J. Creighton
J. R. Musgrave	J. C. Warner
C. C. Rose	H. J. Read

Report of the Chlor-Alkali Committee of the Industrial Electrolytic Division for the Year 1953

William Cecil Gardiner[1]

Production Capacity

The last report of this committee was on May 5, 1952 so this report covers events of 1952 and 1953. The estimated capacity at the end of 1951 was 7200 tons of chlorine per day, but at the end of 1953 it was 9800 tons. This capacity was 0.8% by the nitrosyl chloride process, at one plant, 6.5% from sodium cells, at four plants, 16.0% from mercury cells, at eleven plants, and the remaining 76.7% from diaphragm cells. There are now 63 operating chlorine plants with two more to be completed soon.

Caustic soda production capacity at the end of 1953 was estimated to be 12,155 tons, of which 18.5% was by the lime-soda process and the rest electrolytic.

Actual chlorine production was 2,517,913 tons in 1951, 2,608,690 tons in 1952, and 2,794,320 tons in 1953 or 6900, 7100, and 7640 average daily tons, respectively. Production averaged 7450 tons per day in January 1953, increased to 7840 tons per day in June. In December, production decreased to a daily average of 7330 tons.

New Facilities

Expansions started in the past two years were all completed by the end of 1953 except the Wichita, Kansas, plant of Frontier Chemical Company, the Montague, Michigan, plant of Hooker Electrochemical Company, and the Brunswick, Georgia, plant of Hercules Power Company. These should be in operation in 1954. This expansion has been with seven mercury cell plants using three types of cells, 17 diaphragm cell plants using four types of cells, and two chemical chlorine processes.

The following new electrolytic chlor-alkali plants have been completed in this period:

Allied Chemical & Dye Corporation, Solvay Process Division, Moundsville, W. Va. (Solvay mercury cells)

Frontier Chemical Company, Wichita, Kans. (moved Hooker cells from Pittsfield, Mass., also expanding)

Mathieson Alabama Chemical Corporation, McIntosh, Ala. (Mathieson mercury cells)

North Carolina Pulp & Paper Company, Plymouth, N. C. (deNora mercury cells)

Pennsylvania Salt Manufacturing Company, Calvert City, Ky. (deNora mercury cells)

Monsanto Chemical Corporation, Muscle Shoals, Tenn., and Anniston, Ala. (deNora mercury cells)

Expansions have been completed at the following:

Allied Chemical & Dye Corporation, Hopewell, Va. (oxidation of by-product NOCl to release Cl_2 and regenerate HNO_3)

Allied Chemical & Dye Corporation, Solvay Process Division, Baton Rouge, La. (diaphragm cells), Syracuse, N. Y. (mercury cells)

Brown Company, Berlin, N. H. (Hooker diaphragm cells)

Columbia-Southern Chemical Corporation, Barberton, Ohio, Corpus Christi, Texas, Lake Charles, La., and Natrium, W. Va. (Hooker diaphragm cells)

Diamond Alkali Corporation, Houston, Texas, Painesville, Ohio, and Pine Bluff, Ark. (Diamond diaphragm cells)

Dow Chemical Company, Freeport, Texas, and Midland, Mich. (Dow diaphragm cells)

Hooker Electrochemical Company, Niagara Falls, N. Y., and Tacoma, Wash. (Hooker diaphragm cells)

Niagara Alkali Company, Niagara Falls, N. Y. (Niagara Alkali round type diaphragm cells)

Velsicol Corporation, Memphis, Tenn. (Hooker diaphragm cells)

Wyandotte Chemical Corporation, Wyandotte, Mich. (Hooker diaphragm cells)

A sodium plant under construction at Ashtabula, Ohio, for National Distillers was stopped because a major customer changed plans.

Two Canadian plants, previously announced, are producing. The Marathon Paper Company built a plant at Marathon, Ontario, using deNora mercury cells and Western Chemicals Ltd. built a plant at Duvernay, Alberta, using Hooker Type S diaphragm cells.

An interesting process development to watch will be the Hercules Powder Company's plant at Brunswick, Georgia. The process is licensed from Dow and Grosvenor Laboratories for the indirect oxidation of HCl in a ferric oxide-ferric chloride mass. HCl is a by-product of toxaphene manufacture.

The Muscle Shoals plant operated by Monsanto for the U. S. Corps of Engineers has been kept in stand-by condition. Late in 1953 it was offered for lease by private industry.

The new mercury cell plants have been felt in the mercury market. The 1953 industrial consumption of mercury rose 23% above 1952 largely because three mercury cell plants were opened and capacity at another was expanded. Mercury was returned to the market from a plant closed down in Jersey City, New Jersey. In spite of this, mercury prices dropped during 1952 from \$217–219 to \$187–189 per flask (\$2.85–\$2.88 to \$2.46–\$2.49 per lb). Annual mercury consumption by the chlor-alkali industry in 1949 was 755 flasks. This increased to 2507 flasks in 1952 and 2378 in 1953. This last figure was 4.5% of the U. S. consumption.

Chlorine End Use

The estimated end use of chlorine is as follows:

	%
Solvents	25
Plastics and fibers	15
Pesticides and herbicides	15
Pulp and paper	14
Automotive fluids	13
Refrigerants and propellants	11
Sanitation	4
Miscellaneous	2
	100

[1] Divisional Editor, Industrial Electrolytic Division. Mathieson Chemical Corporation, Niagara Falls, New York. Prepared for delivery before the Chicago Meeting, May 2 to 6, 1954.

Future Outlook for Chlorine

Considering the broad and expanding end uses of chlorine, the yearly chlorine consumption is expected to show an annual increase of 7 9% up to 1960.

The chlorinated solvents, carbon tetrachloride, chloroform, methylene chloride, trichloroethylene, perchloroethylene, etc., should remain over the next ten years as the major outlets for chlorine.

The growing acceptance of fibers and plastics derived from chlorine will make a major contribution to chlorine expansion. Foremost are vinyl chloride and vinylidene chloride polymers used in household floor tile, curtains, seat covers, etc. Phenolics for foundry shell molds and for bonding wood waste will show conservative gains. Chlorine use in phenolics will be limited by the competition of the Raschig process to make phenol (benzene, HCl, and air) with the chlorination of benzene process. Likewise the meteoric rise in ethylene glycol-terephthalates and acrylonitrile for synthetic fibers will augment chlorine consumption only where the chlorohydrin process is used to make ethylene oxide. Kel-F growth is a certainty. The rising acceptance of the silicones will reflect in turn a greater need for methyl chloride.

Indications are that the herbicide 2,4-D demand will level off and 2,4,5-T will continue to grow at its current rate. The phenomenal rise in the use of chlorinated insecticides (BHC, DDT, chlorodane, aldrin, and toxaphene) will be difficult to match in the future. Lindane, the 100% gamma isomer of BHC, is currently the fastest growing. Pentachlorophenol, mainly used as a wood preservative, should show gains over its past record.

Pulp and paper requirements for chlorine are expected to remain at about the present level over the next few years.

Growth in automotive fluids, ethylene glycol, and tetraethyl lead will increase the chlorine demand moderately. Chlorine for manufacture of glycol will be limited to the chlorohydrin process. TEL fluid contains or requires for its production ethyl chloride and ethylene dichloride. The greater number of automobiles and the trend toward higher compression engines tend to increase the use of TEL and glycol. The shift to jet engines for aircraft and the increasing use of aromatics offsets this trend somewhat. Milder winters and the suggestion (by car manufacturers) to use glycol antifreeze for several winters are affecting the market.

The market for ethylene glycol is growing outside its use as antifreeze. *Chemical Week* reports that over 70% of the glycol produced in the past few years has gone into such end uses as plasticizers and synthetic rubber. The trend toward direct oxidation of ethylene rather than the chlorohydrin process to obtain ethylene oxide means that chlorine requirements will not keep pace with these new glycol outlets.

Refrigerants and propellants consisting of du Pont Freons and General Chemical's Genetrons, a series of fluoro-organics, should maintain their annual growth. Methyl chloride used as a refrigerant should bolster chlorine consumption in this application.

The Caustic Soda Picture

The growth curve for chlorine consumption has been at a faster rate than for caustic soda. At this time, electrolytic caustic soda capacity comes very close to being able to supply the market. Lime-soda plants make up the difference. Favorable location and high quality of product provide outlets for some lime-soda producers even when electrolytic caustic is difficult to sell. This causes a prospective chlorine producer to study well how new caustic soda is to be handled.

Use of by-product HCl from the chlorination of organics is a growing factor in balancing the chlorine-caustic soda situation. Some of the means being used or considered are:

1. The conversion of by-product HCl to chlorine. Hercules is building a plant for doing this at its Brunswick, Georgia, toxaphene plant.
2. The Raschig process makes phenol from benzene, HCl, and air in competition with the direct chlorination of benzene.
3. The manufacture of ethyl and vinyl chloride from ethylene-HCl and acetylene-HCl, respectively.

Acknowledgment

Mr. Axel Heilborn, Niagara Alkali Company, Mr. Morton S. Kircher, Hooker Electrochemical Company, Mr. Robert B. MacMullin, R. B. MacMullin Associates, and Mr. Warren D. Sherrow, Great Lakes Carbon Corp., assisted in this report.

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Current Affairs

Looking Back on the Chicago Meeting

Based on the content of the technical program, the Chicago Meeting was as new as the transistor. However, the presence of many of the Society's long-time members and friends lent the atmosphere of the "good old days." It was particularly gratifying to see Mrs. Lottie Fink in attendance and to reminisce with her about former meetings at which she and her husband and one secretary handled the entire meeting! Perhaps Mrs. Fink can be joined by her son Fred at the Boston Meeting this fall.

The quality of the technical sessions represented a high point in the history of the Society. The variety and significance of the subjects covered certainly place the meeting in the ranks of the finest ever held. In fact, many comments were heard to the effect that the program was "too good." Many papers had to be passed up simply because something else was going on simultaneously which "couldn't be missed." The Division Chairmen and their assistants who organized the special symposia, round tables, and technical sessions are to be congratulated.

The men were not alone in having a technical program—the ladies, too, were given a lecture. Of course, it was not electrochemical, but it had certain *chemical* aspects. On Tuesday afternoon many of the ladies made a trip to the Helena Rubenstein salon, where they heard the latest on skin care, complete with a demonstration. The local committee takes no responsibility for a bit of advice which was reportedly given, to the effect that a lady should not wash her face!

The trip to the Baha'i Temple on Monday afternoon and the fashion show and matinee on Wednesday seemed to be well received. In addition, there were small groups who went to Chinatown, the Art Institute, and other points of interest, depending on personal choice. Several comments were received to the effect that there was something of interest to everyone.

The Ladies' Committee was extremely pleased to have Mrs. F. C. Mathers present at the meeting. Her complete recovery from a recent operation was evidenced by her participation in nearly all of the events of the week. In fact, it is rumored that she and Professor Mathers will make a trip to Japan in the near future.

With the very large attendance at the meeting (about 750), the problem of registration was a difficult one. The primary objective was to complete an individual's registration and ticket purchases as rapidly as possible, so that his waiting-time would be minimized. Of course, that meant that the red tape of record-keeping had to be simplified as much as possible. It seems that a reasonable compromise was reached, since even at the peak registration periods the longest waiting-time was only about 10 minutes.

Another testimonial to the great drawing power of the technical sessions was the very low participation in the plant trips. A small group went to see the cable manufacturing operation at Western Electric. Another group had lunch at the E. H. Sargent Company plant and made a tour of their manufacturing and laboratory facilities. A few went to see the television tube screen application plant at the Rauland Corporation (Zenith). In all cases it was reported by the returning groups that the finest hospitality was extended by each of the companies visited.

It was difficult to estimate the number who would be in attendance at each of the technical sessions for purposes of room assignments. In general, however, the meeting rooms seemed adequate. In one particular case (the Lincoln Room on the 18th floor), a round-table discussion had to be converted to a "rectangular" session due to room geometry. Otherwise, it is felt that the LaSalle provided exceptionally good facilities. There was one instance of faulty PA system operation (Century Room, Monday morning), which was quickly repaired during the noon hour. The trouble evidently came from a bad connection, possibly caused by certain building alterations which were proceeding during the meetings (perhaps in hopeful preparation for the 1960 meeting).

As far as food was concerned, the Monday evening buffet lived up to expectations and the Tuesday banquet (filets) was certainly enjoyed by all. Some excellent reports were received on the several luncheons (there were a total of five held). Some complaints registered on one of the Monday luncheons were passed on to the hotel management and resulted in a meeting of the Maître d'Hôtel's staff on Tuesday.

At the General Society Luncheon, President McKay and President-Elect Udy enjoyed conversations with the speaker, Mr. Casper W. Ooms. It seems that Mr. Ooms was engaged in the chromium plating litigation many years ago and has more than a little interest in the electrochemical landmarks of our history. He later presented some very thought-provoking ideas on the relation between government, inventors, and atomic energy.

The number of visitors from other countries was quite large. One who seemed to enjoy her visit particularly was Mrs. M O. Sem. She and her husband had been touring the U. S. for some time before coming to Chicago, and were planning to return to Norway shortly. Evidently an experienced traveler, Mrs. Sem casually mentioned that this would be her twelfth crossing of the Atlantic!

Another visitor was Dr. J. T. Kendall of England, who spent a few hours Wednesday evening watching television for the first time in one of the local section rooms. It should be noted that a particularly good assortment of programs was provided for Dr. Kendall. The fights were on when he arrived. They were followed by a session with Liberace, then selections from the McCarthy-Army hearings. Upon being asked which of the programs impressed him the most, he replied that the commercials were the most astounding. Reflecting a little, all present agreed.

One of the visitors from France was positively delighted when he discovered

an American sitting near him during the Monday evening entertainment who could speak French. They conversed for some time, after which the visitor was quite apparently at ease.

A number of amusing minor incidents should be mentioned. It seems that Hans Neumark attended the meeting alone. On inquiry, it was learned that his wife did not accompany him because of the recent arrival of a baby daughter. Hans confided that he was sleeping soundly in his hotel room for the first time in seven weeks!

Several people remarked to Local Committee members that they were particularly appreciative of the write-up on "What to See and Do in Chicago," which appeared in the March JOURNAL. It turned out, however, that they were referring to the section which gave advice on places *not* to visit! It became evident during the meeting that this advice was not properly heeded. The following occurred on Wednesday morning: the telephone rang at the registration desk and was answered by a committee member. The message was for a certain Mr. "X," and stated that he should call Officer So-and-So at the

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Seen at the Chicago Meeting

I—The well-organized registration desk. II—Tuesday evening reception and banquet for the President; left to right in the receiving line are President and Mrs. McKay and Vice-Presidents Udy and Thurnauer. III—Also in the Ballroom Tuesday, Dr. and Mrs. O. W. Storey and Mr. and Mrs. G. W. Heise. IV—G. L. Martin and A. L. Smith talk it over comfortably. V—The ladies gather to renew acquaintanceship and make plans. VI—J. P. Oliver, H. R. Neumark, and N. J. Johnson carry on a relatively serious conversation. VII—R. J. McKay, E. A. Gulbransen, and C. K. Morehouse, ditto. VIII—W. C. Gardiner delivers his summary of chlorine-caustic production before the Industrial Electrolytic Round Table. IX—There's nothing serious about the chat among Mrs. C. G. Fink and Mr. and Mrs. C. A. Hampel. Talking continues: X—M. G. du Bellay, Robert Misch, B. Ydstie, and C. V. King. XI—W. G. Dicks, B. F. Freeberg, H. S. Hooper, and E. W. Murbach. XII—K. B. McCain, A. C. Loonam, and R. E. Cushing. XIII—P. S. Brallier, C. B. Brown, A. H. B. Sturton, and F. M. Berkey.

Technical Review

The Utility of Thermodynamic Interpretation of Polarization Curves

Marcel Pourbaix[1]

Abstract

A description is given of several principles related to the thermodynamic interpretation of polarization curves: reaction potential, equilibrium potential, affinity, overvoltage, direction in which an electrochemical reaction occurs, and polarization curves of an electrochemical reaction.

Applications to some particular cases are given: (*a*) experimental determination of the thermodynamic equilibrium potential of an irreversible reaction; (*b*) determination of oxidation reduction catalysts; (*c*) prediction of conditions of corrosion and passivity of metals and alloys; behavior of mild steel in a bicarbonate medium; behavior of stainless steel in acetate buffer, influence of chlorides; action of chlorides on the corrosion of iron and the remedy for this action; prevention of localized corrosion.

Principles

Reaction potential and equilibrium potential, affinity, overvoltage, direction in which an electrochemical reaction occurs, and polarization curve of an electrochemical reaction (1).—The direction in which a thermodynamically possible electrochemical reaction, r, occurs at the interface between a metal and an aqueous solution is determined by relative values of the reaction potential E' of the metal surface and of the equilibrium potential E_r of the reaction. When the potential E' of the metallic surface is higher than the equilibrium potential E_r of the reaction, this reaction can be brought about only in the direction of an oxidation; when the potential E' is lower than the equilibrium potential E_r, the reaction can be brought about only in the direction of a reduction.

It should be understood that these potentials are both computed with respect to the same reference electrode and are related to the same physicochemical state of the substances taking part in the reaction; that is to say, particularly to the same conditions of temperature, fugacity (for the gaseous reaction products), and activity (for dissolved reaction products). Reaction potential E' can be measured experimentally according to the classical method of Haber and Luggin,[2] utilizing a siphon whose capillary extremity dips into the solution in the immediate proximity of the metallic surface; equilibrium potential E_r of the reaction can be calculated thermodynamically.[3]

If one uses for electrochemical reactions the relation of de Donder (5)

$$A.V > 0$$

which relates the direction of the reaction (determined by the sign of the rate V) to the sign of its affinity A, one obtains the relation (6)

$$(E' - E_r) \cdot i_r > 0$$

where the difference $E' - E_r$ between the potential E' of the metallic surface and the equilibrium potential E_r of the reaction is in quantity and in sign the affinity divided by n Faradays or the overvoltage[4] of this reaction on this surface; the reaction current i_r, which measures, according to Faraday's law, the rate of reaction r is to be considered as positive in the case of oxidation and as negative in the case of reduction. Relation $(E' - E_r) \cdot i_r > 0$ states, in short, that the rate of an electrochemical reaction is always either zero or of the same sign as its overvoltage.

The characteristics of irreversibility of an electrochemical reaction brought about at the interface between a metal and an aqueous solution can be represented by a polarization curve $E' = f(i_r)$. This curve expresses in short the relation $E' - E_r = \varphi(i_r)$ between the affinity $E' - E_r$ and the rate i_r of the reaction, if this curve is determined by avoiding any concentration polarization, i.e., if the equilibrium potential E_r of the reaction is maintained practically at the same value for the different reaction rates i_r (this can then be the case generally only when experiments are made in solutions which are sufficiently agitated and buffered).

If one plots positive potentials in ordinates upward and

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[1] Belgian Center for the Study of Corrosion, University of Brussels, Brussels, Belgium. Paper prepared for delivery before the Philadelphia Meeting, May 4 to 8, 1952.

[2] Haber (2) seems to have been the first to recognize, in 1898, the great importance of electrode potential on the course of electrochemical reactions; Haber, in collaboration with Luggin in 1900 (3), has indicated a method for the measurement of this potential.

[3] If one takes arbitrarily as equal to zero the equilibrium potential of the electrochemical reaction of the reference electrode (e.g., $H_2 = 2H^+_{aq} + 2e^-$ in the case of the hydrogen electrode) and the free energies of formation of H_2 at one atmosphere and H^+_{aq} at $pH = 0$, the equilibrium potential E_r in volts of an electrochemical reaction of the type $\Sigma\nu M + ne^- = 0$, of which the constituents M have free energies of formation μ (in calories), has the value:

$$E = \frac{\Sigma\nu\mu}{23{,}060\ n}$$ [see (4)]

[4] Thus defined, the overvoltage corresponds to the "Fehlspannung," an idea proposed by Lange and Nagel in 1937 (7).

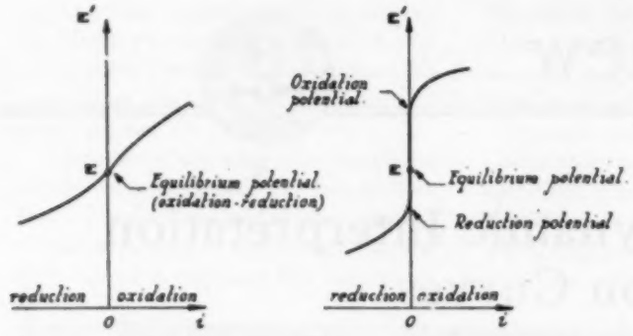

FIG. 1*a* and 1*b*. Types of polarization curves. Fig. 1*a*, left, reversible reaction in the two directions; Fig. 1*b*, right, irreversible reaction in the two directions.

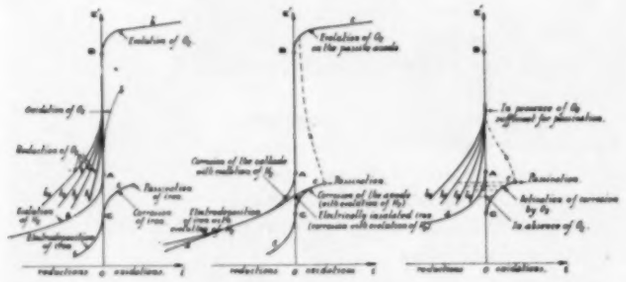

FIG. 2*a*, 2*b*, and 2*c*. Polarization curves and behavior of iron. Fig. 2*a*, left, polarization curves, curve a, $H_2 = 2H^+ + 2e^-$, curve b, $2H_2O = O_2 + 4H^+ + 4e^-$, curve c, $Fe = Fe^{++} + 2e^-$; Fig. 2*b*, center, behavior of iron electrode in a solution initially free from hydrogen and oxygen; Fig. 2*c*, right, action of increasing quantities of oxygen on the behavior of electrically insulated iron.

the positive currents, or rates of oxidation, in abscissas toward the right, polarization curves are, according to relation $(E' - E_r) \cdot i_r > 0$, ascending from left to right and intersect the axis of ordinates at a point corresponding to the equilibrium potential E_r of the reaction (Fig. 1).

According to this method of representation, in the case of reactions which are reversible in both directions (Fig. 1*a*), for which a small affinity $E' - E_r$ (positive or negative) is sufficient in order to bring about an appreciable rate (in the direction of oxidation or reduction), the polarization curve intersects the axis of ordinates at a point where $E' = E_r$ (equilibrium potential of the reaction). In this case, an electrode in contact with the oxidation-reduction system acquires the equilibrium potential; the value of this potential is the thermodynamic equilibrium potential. This equilibrium potential is measurable, e.g., Pt in the presence of $Fe^{++}{}_{aq}/Fe^{+++}{}_{aq}$, platinized Pt in the presence of $H_2/H^+{}_{aq}$, Tl in the presence of $Tl^+{}_{aq}$.

In the case of reactions which are practically irreversible in both directions (Fig. 1*b*), rate of reaction remains practically zero for measurable values of the affinity (positive and negative), the polarization curve coincides practically with the ordinate axis on each side of the point representing the equilibrium potential E_r. The curve departs from this axis only when the overvoltage exceeds in absolute value a certain critical value which measures the potential barrier or the "activation overvoltage" relative to the reaction. There exists, then, according to definitions proposed by Van Rysselberghe (8), an oxidation potential above which the reaction actually occurs in the direction of oxidation, and a reduction potential below which the reaction occurs in the direction of reduction; the potential E_r corresponding to thermodynamic equilibrium of oxidation-reduction is situated

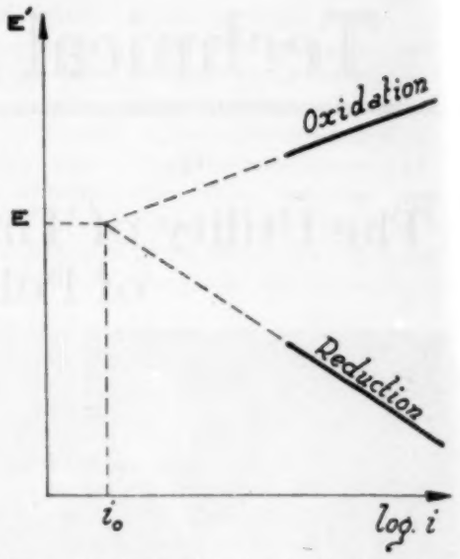

FIG. 3. Catalysis of electrochemical reaction

between these two potentials. In the case of such irreversible reactions, one electrode placed in contact with the oxidation-reduction system shows a potential generally unstable which can vary between the oxidation potential and the reduction potential; the equilibrium potential is not experimentally measurable directly (e.g., Pt in the presence of O_2/H_2O).

In the very frequent case of simultaneous electrochemical reactions occurring on the same metallic surface, analysis of the complex phenomena which result may be generally effected in a sufficiently approximate manner by means of a simple superposition of polarization curves corresponding to each of the reactions. Fig. 2, on the subject of which discussion appears elsewhere (1), illustrates an example of the use of polarization curves in the behavior of iron. The classical work of Evans in the use of polarization curves in the study of "local elements" in corrosion (9) may be considered as the basis of the science of corrosion of metals in aqueous solutions. Wagner has shown in a fundamental treatment of the corrosion of zinc amalgams (10) that the method of superposition of polarization curves is applicable even in the absence of local action. Pourbaix has applied this method in the study of different electrochemical phenomena related in particular to the corrosion of iron (11) [see also Reference (1), p. 471]. Bonhoeffer has demonstrated experimentally the validity of this method of superposition of polarization curves in the corrosion of iron in the presence of H_2SO_4 (12).

Applications

Four cases in which the thermodynamic interpretation of polarization curves has been useful are discussed.

Experimental Determination of Thermodynamic Equilibrium of an Irreversible Reaction[5]

It is well known that polarization curves generally follow Tafel's law, $E' = a + b \log i$, where i is the absolute value of the reaction current.

In the case of the reaction $O_2 + 4H^+ + 4e^- = 2H_2O$ on Pt and on Au, Hoar (13) observed that, if one extrapolates logarithmically according to Tafel's law, the oxygen polarization curve $2H_2O \rightarrow O_2 + 4H^+ + 4e^-$ and that related to the reduction $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$, these curves intersect at the thermodynamic equilibrium potential of the reaction (Fig. 3). Bowden and Agar (14) have suggested a considera-

[5] *See* Reference (1), p. 14.

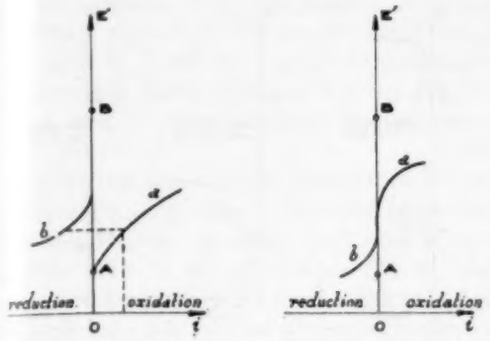

FIG. 4*a* and 4*b*. Polarization curves and electrochemical catalysis of chemical reaction. Fig. 4*a*, left, catalysis; curve a, $2H_2 = 4H^+ + 4e^-$, curve b, $2H_2O = O_2 + 4H^+ + 4e^-$; Fig. 4*b*, right, no catalysis; curve a, $2H_2 = 4H^+ + 4e^-$, curve b, $2H_2O = O_2 + 4H^+ + 4e^-$.

tion of the two reaction currents thus extrapolated at the equilibrium potential as a measure of the catalytic activity of the electrode for the reaction. In the case of the reaction $O_2 + 4H^+ + 4e^- = 2H_2O$ studied by Hoar, this current was from 10^{-13} to 10^{-12} amp/cm^2.

Prediction of Oxidation-Reduction Catalysts[6]

When, for a same metallic surface, two polarization curves related, respectively, to (*a*) an oxidation reaction, e.g., $2H_2 \rightarrow 4H^+ + 4e^-$, and (*b*) a reduction reaction, e.g., $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$, are such that values of the potential exist for which both reactions take place with measurable rates (Fig. 4*a*), it follows[7] that the metallic surface is likely to catalyze electrochemically the resulting chemical reaction ($2H_2 + O_2 \rightarrow 2H_2O$) if the reaction medium contains simultaneously the oxidant (O_2) and[7] the reducing agent (H_2). The metal then acquires, if electrochemically insulated, the potential at which the two reaction currents are equal in absolute value. This value of the current measures the rate of the over-all catalyzed reaction. On the other hand, when polarization curves are such that there is no potential at which both reactions occur with a measurable rate (Fig. 4*b*), the metal surface is not likely to catalyze the resulting reaction. As far as is known, this interpretation has not yet been the object of any experimental work.

Prediction of Corrosivity and Passivity of Metals and Alloys[8]

Here again are given, with some modifications and developments, considerations previously presented in collaboration with Van Rysselberghe (16), with the object, in part, of determining under what conditions a particular metal or alloy is corroded or not corroded by a given solution, and also of

[6] *See* Reference (1), p. 466.

[7] Unpublished discussion among J. Weydema, W. G. Burgers, and M. Pourbaix.

[8] Assume that there is immunity, or cathodic protection, of a metal when this metal, although presenting a real metallic surface, is thermodynamically stable; all corrosion of the metal is then thermodynamically impossible. Consider that there is passivation when the surface of the metal is not really metallic, but is covered by a film or deposit of oxide, salt, or some extraneous material. Consider that there is passivity when, although thermodynamically unstable, the metal does not corrode practically; there is passivity by inertia when the absence of corrosion is due to irreversibility of the corrosion reaction, as could be the case with zinc and nickel; there is passivity resulting from coating when the absence of corrosion is due to a passivation, by the formation of a film or deposit of an oxide or salt or extraneous material (15).

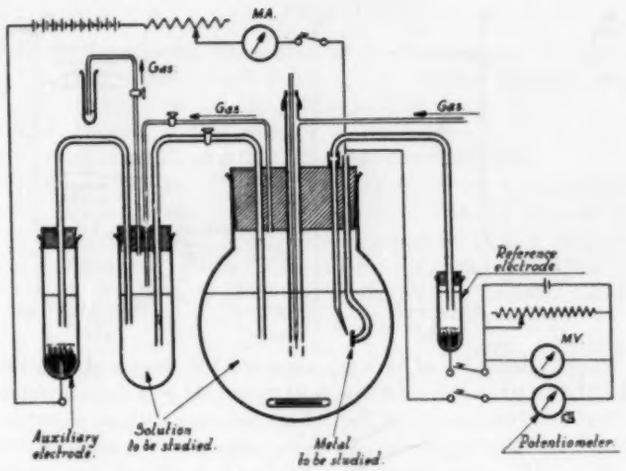

FIG. 5. Apparatus

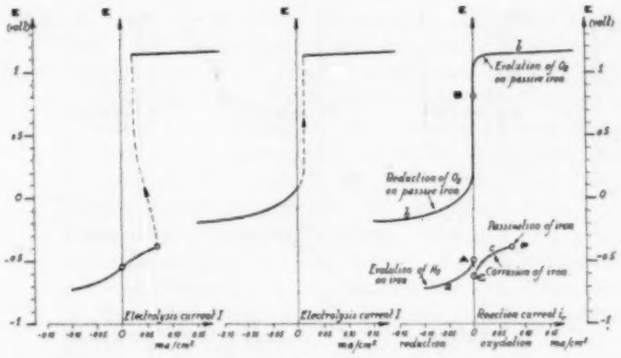

FIG. 6. Behavior of mild steel in a solution of $NaHCO_3$ 0.10 mole, *p*H 8.6. Left, degassed solution; center, solution saturated under 1 atm; right, polarization curves, curve a, $H_2 = 2H^+ + 2e^-$, curve b, $2H_2O = O_2 + 4H^+ + 4e^-$, curve c, $Fe = Fe^{++} + 2e^-$.

determining which modifications in the composition of an alloy or metal or solution may prevent corrosion. Three cases will be given as examples.

Behavior of mild steel in a bicarbonate solution[9].—By means of the experimental arrangement shown in Fig. 5, an ordinary mild steel electrode, previously descaled, is polarized cathodically and anodically and placed in a solution of $NaHCO_3$ 0.1*M* of *p*H 8.6 strongly stirred and rendered free of oxygen by degassing under vacuum. The electrolysis curve shown on the left side of Fig. 6 is obtained. The anodic curve is composed of two stable branches, one at a low and the other at a high potential. If the same electrode placed in the same solution saturated with oxygen at a pressure of one atmosphere is polarized, electrolysis curves shown in the center of Fig. 6 are obtained.

Knowing the *p*H of the solution (8.6), one is able to determine easily the points A and B of the right part of Fig. 6 which correspond, respectively, to the equilibrium potential of the reaction $H_2 = 2H^+ + 2e^-$ (−0.51 v) and to the equilibrium potential of the reaction $2H_2O = O_2 + 4H^+ + 4e^-$ (+0.72 v). In the case of a solution practically free from iron, the equilibrium potential *C* relative to the reaction $Fe = Fe^{++} + 2e^-$ is about −0.60 v. It is now easy to trace the polarization curves of these three reactions (right part of Fig. 6).

[9] *See* Reference (16), p. 220. The author's experiments mentioned in (1) and (2) were made in August 1949 in the laboratories of the National Bureau of Standards, with the collaboration of I. A. Denison, B. J. Mair, and W. J. Schwerdtfeger.

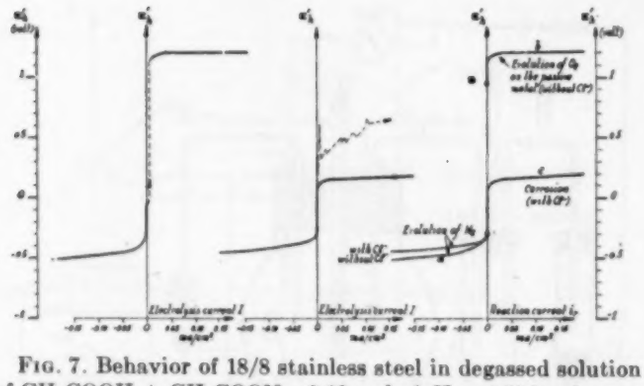

FIG. 7. Behavior of 18/8 stainless steel in degassed solution of $CH_3COOH + CH_3COONa$, 0.10 mole (pH = 4.9) in absence of NaCl and in presence of NaCl. Left, solution without chloride; center, solution with chloride, right, polarization curves; curve a, $H_2 = 2H^+ + 2e^-$; curve b, $2H_2O = O_2 + 4H^+ + 4e^-$; curve c, $Fe = Fe^{++} + 2e^-$.

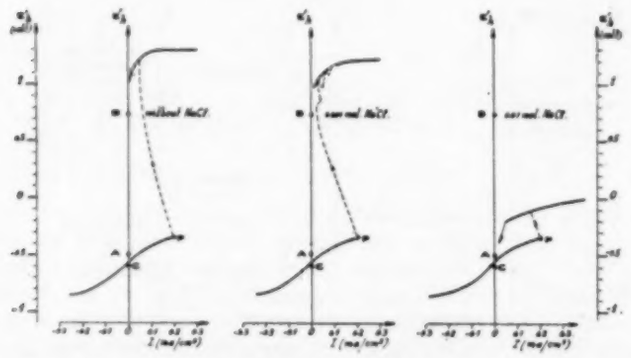

FIG. 8*a*, 8*b*, and 8*c*. Influence of chloride on the behavior of mild steel in a solution of $NaHCO_3$, 0.10 molar (pH 8.4) in absence of oxygen (degassed solutions).

The result shows that if the passive film which is formed at point P prevents completely corrosion (which, in a solution free from any trace of reducing agent, is shown by the absence of any stable anodic current between the points P and B), the corrosion of steel is possible only for potentials between C and P; corrosion is impossible for potentials below C, in which case there is immunity or cathodic protection; corrosion is impossible for potentials above P. These general conditions of corrosion hold whatever the reason for which a metal acquires any particular potential.

It is easy on this basis to determine the conditions under which differential aeration occurs (as elucidated by Evans), to explain the activating or passivating effect of oxidizing inhibitors (17), and, in a general way, to predict the treatments to be employed to protect mild steel in bicarbonate solutions.

Behavior of "stainless steel" in acetic solution—influence of chlorides[10].—If 18-8 stainless steel is polarized cathodically or anodically, as indicated above, in a solution of acetic acid and sodium acetate of pH 4.9, strongly stirred and degassed, electrolysis curves shown on the left side of Fig. 7 are obtained. The anodic curve presents only one stable branch which is observed at potentials more positive than the equilibrium potential (+0.94 v) of an oxygen electrode immersed in the solution (reaction $2H_2O = O_2 + 4H^+ + 4e^-$). As a result, no oxidation is possible in the potential range (below +0.94 v) exhibited by electrically insulated steel. This steel is therefore corrosion resistant under these conditions.

If the same electrode is polarized in the solution obtained

[10] *See* Reference (16), p. 227.

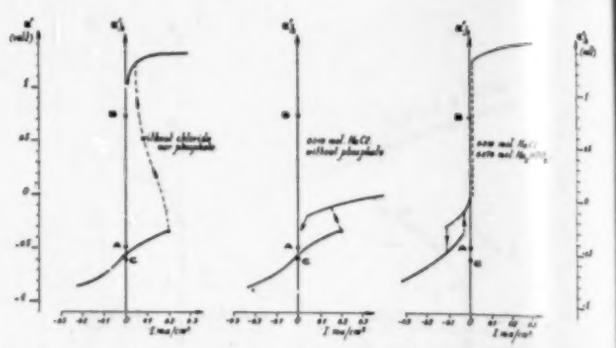

FIG. 9*a*, 9*b*, and 9*c*. Influence of chloride and of phosphate on the behavior of mild steel in a solution of $NaHCO_3$, 0.10 molar in absence of oxygen (degassed solution).

by the addition of sodium chloride to the acetic solution above, the anodic polarization curve instead of being located entirely above the equilibrium potential of the oxygen electrode is located below this potential. This indicates an oxidation of the metal and a high corrosion rate. When the polarization curve at increasing current densities is determined, irregularities connected with the local formation and destruction of a film which leads to localized corrosion are observed. Such tests readily show that 18-8 steel, which does not corrode in pure acetate solutions, is strongly corroded by acetate solutions containing chlorides.

Action of chloride on the corrosion of iron and remedy for this action.—In collaboration with Feron, the author investigated, by means of the above-mentioned method, the influence of chlorides on the electrochemical behavior of mild steel in degassed solutions 0.10M of sodium bicarbonate (18). Results obtained are shown on Fig. 8.

In the absence of chloride, the anodic polarization curve shows two stable branches represented in Fig. 8*a*. One of these branches, in the range of potentials between the equilibrium potential of the metal C (about −0.60 v), and its passivation potential, P (−0.35 v), corresponds to the corrosion of the metal. The other branch, at potentials above the equilibrium potential of the oxygen electrode, B (+0.72 v), corresponds to the evolution of oxygen without corrosion. Corrosion of the metal is, therefore, possible only between −0.60 v (C) and −0.35 v (P); below −0.60 v, the metal is cathodically protected; above −0.35 v the metal is protected by passivation.

Incorporation of increasing quantities of chloride in the solution (Fig. 8*b* and 8*c*) does not modify the circumstances of cathodic protection nor the value of the passivation potential P, but the result is that it permits the flow of more and more current between the passivation potential P and the potential of the oxygen electrode B. This is related to the appearance of strong local corrosive attack.

Consequently, it is among the anions likely to stabilize the protective oxide film with the formation of slightly soluble ferric salt that a remedy for the activity of chlorides may be discovered. Furthermore, the effectiveness of this remedy will be such that all current between potentials P and B will be suppressed and that the type of anodic polarization curve existing in the absence of chloride (Fig. 8*a*) is again observed. This remedy will be completely effective if it enables one to obtain polarization curves similar to those in Fig. 7*a*, i.e., oxidation curve which presents only one branch located entirely above the potential B of the oxygen electrode. In this case, no corrosion is possible and the remedy is perfect.

Preliminary experiments were carried out on the effect of the addition of increasing quantities of disodium phosphate

in degassed solutions of 0.10*M* sodium bicarbonate and 0.010*M* sodium chloride. It was observed that, for additions at least 0.07*M* in Na_2HPO_4, the anodic polarization curve corresponds to the above condition (Fig. 9c). All corrosion is avoided, at least by potentials above the passivation potential P (−0.35 v).

Consider the fact that cathodic polarization of iron in such solutions reveals an activation of the metal below the passivation potential. It seems, therefore, that even in the absence of phosphate (19) the protective oxide film is dissolved by reduction at such potentials. It has not yet been determined whether phosphate also protects the metal in these reducing conditions and it is possible that danger of corrosion exists under these conditions. In the present state of these studies, it seems that, in order to protect iron and unalloyed steels completely by passivation in the presence of chloride solutions, it is necessary to use mixed inhibitors containing a substance like phosphate which prevents all oxidation current at potential higher than the passivation potential, and an oxidant (chromate, nitrite, etc.) preventing the existence of potentials below the passivation potential.

Since chlorides do not modify the potential at which iron is protected cathodically, cathodic protection of iron and ordinary steel is possible in the presence of, as well as in the absence of, chloride, provided that in both cases the potential be decreased below a well-defined value (−0.60 v for *p*H below 10).

Prevention of Localized Corrosion

One important question concerning the protection of iron and nonalloyed steel remains unsolved, that is, how to avoid localized corrosion due to chlorides and to unsafe inhibitors (pitting).

This pitting seems to be caused in the majority of cases by phenomena of differential oxidation which, as Evans has shown in the case of oxygen, result in local currents between cathodes (where the potential is higher than the passivation potential and at which the oxidizing agent is reduced) and anodes (where the potential is below the passivation potential and at which the metal corrodes).

Two groups of remedies are possible for this type of corrosion. Cathodic protection can be applied by bringing the potential of all parts of the surface below −0.60 v (for *p*H below 10); or mixed inhibitors can be used, for instance, the mixture of phosphate and oxidant mentioned above, which prevents any oxidation of the metal below the equilibrium potential of the oxygen electrode. Systematic researches concerning the determination and thermodynamic interpretation of polarization curves are likely to lead to a satisfactory solution of this problem.

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Feature Section

Research and Development in the Field of Carbides, Nitrides, Silicides, and Borides for Aircraft Propulsion

A Status Report

Lloyd D. Richardson, Sr.[1]

Introduction

The Air Force is pleased to provide this status report concerning its research and development effort in the field of ceramic materials for use in high temperature areas of aircraft.

First, the reasons the Air Force is interested in ceramic materials in general will be discussed; second, a brief history of this research and development effort is described, and third, the reasons the Air Force is considering materials like carbides, nitrides, borides, aluminides, silicides, titanides, and graphite are given.

The reason that the Air Force is interested in the use of ceramic materials in the high temperature areas of aircraft is threefold. First, certain essential components in aircraft must resist temperatures in excess of 1200°F and corrosive atmospheres. To provide this necessary resistance, unfortunately, metals of a strategic nature must be utilized and, in the event of world conflict, the availability of such materials is greatly reduced. Second, the ability of ceramic materials to withstand high temperatures and corrosive atmospheres surpasses that of metals in many instances. Present high temperature alloys have nearly reached their limit of temperature resistance. Third, basic raw materials of ceramics are in many instances cheaper and more readily available than raw materials for high temperature alloys.

With the advent of technological research of the engineering properties of ceramic materials, the term "ceramics" has come to include such materials as metal carbides, nitrides, borides, silicides, aluminides, titanides, etc., along with the oxides of the older connotation.

Research and Development

Examine for a moment what research of the past decade and a half has revealed as concerns properties of bodies made from metallic oxides. At this point, it should be remembered that the proposal has been to substitute directly in present designed jet engines metal oxide bodies for metal bodies. Turbine buckets and nozzle diaphragm blades are typical examples where metal oxide bodies might replace metal bodies. Assuming that such a direct substitution is feasible, let us continue our examination of the problems involved.

Early investigators found that the presence of a glassy bonding phase (one which exhibited a noncrystalline structure) greatly reduced the ability of an oxide ceramic body to resist a large temperature gradient and reduced the physical properties of the material. In addition, early experimentation revealed that bodies produced of pure oxides such as alumina, magnesia, beryllia, silica, and the like, where the glassy phase was eliminated, continued to show poor resistance to large temperature gradients.

Poor thermal shock resistance exhibited by glass bonded ceramics and pure oxide ceramics was attributed to low thermal conductivity, coupled with high thermal expansion. Several notable exceptions to this fact are bodies made from lithium-aluminum-silicate or several of the titanate bodies. These bodies appeared to possess good thermal shock resistance because they exhibit a zero or negative coefficient of thermal expansion. However, they possessed low tensile strength.

The next step in this research and development effort was to find materials which more nearly resembled the metals in their ability to resist sudden changes in temperature and which would possess higher values of thermal conductivity. The effort turned to combinations of metal oxides and corrosion resistant metals. Notable among these materials were the cermets bodies composed of alumina and pure chromium metal. In spite of the fact that this cermet exhibited very favorable high temperature properties, it was eliminated from the list of promising materials on the basis of its poor thermal shock resistance. Some improvements have been made in this material which will be discussed below.

The next step in this progressive program of research was to find a material or materials having thermal conductivities more nearly approaching the level of metals than did the oxide-metal combinations. These materials must also have high melting points and good chemical stability at high temperatures.

Materials which were believed to possess these properties were a group including the metal carbides, nitrides, borides, aluminides, etc. Commercially available materials such as silicon carbide, tungsten carbide, titanium carbide, tantalum carbide, and multi-carbides of tungsten and titanium were investigated. Self-bonded bodies of these materials were investigated for high temperature strength, oxidation resistance, and thermal shock resistance. This work indicated some improvement in thermal shock resistance, but many exhibited poor strength and poor oxidation resistance.

Further improvements in oxidation resistance and thermal shock resistance were discovered in the metal-bonded metal carbides. We have now arrived at that phase in the research and development effort where the major emphasis was placed

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on titanium carbide base material. The reason for this was that titanium carbide appeared to be "wet" readily by a variety of bonding metals, it was readily available, and its production appeared to be economical.

Titanium Carbide

The effort during the last four or five years has been concentrated on titanium carbide. Attempts were made first to improve the purity of the basic titanium carbide material and, second, to improve its properties by proper compositions of bonding materials.

The purity of titanium carbide was investigated for the type of impurity present and where this contaminant was introduced. Free carbon was found in the structure introduced during the carburizing operation. Attempts to remove this free carbon have been reasonably successful in that titanium carbide as we see it today can be produced with a free carbon content of about 0.02% or lower. This reduction in the free carbon content has been achieved by a selective flotation technique. Recent experimentation has revealed that oxygen and nitrogen may be even more serious than free carbon in the structure. Oxygen, nitrogen, free iron, and chlorine are introduced in subsequent ball milling operations when the carburized cake is reduced to a particle size of from 2 to 4 microns suitable for forming into useable shapes. These contaminants originate in the milling media.

As a result, it has been necessary to attempt to find out which ball milling media will introduce the least amount of contaminants. This work has not been completed but will be within the year (1954).

Properties of Titanium Carbide

Improvements in finished titanium carbide base metal-bonded material have been affected by proper composition of the metal binder. Early bodies composed of cobalt or nickel-bonded titanium carbide exhibited low thermal shock resistance. Improvements were made in these bodies by suitable additions of alloying elements such as molybdenum, aluminum, and chromium to the metal binder.

In addition to the improvement in thermal shock resistance, these alloying elements have improved the stress-to-rupture life of these materials.

At this point, attempts were made to subject titanium carbide base materials to simulated engine testing. One important property which investigators believed these materials should possess was the ability to resist high velocity particles which might be introduced into the engine from the outer atmosphere or from parts of the engine itself being carried through the turbine area. Impact testing apparatus was used to simulate this condition.

Modified Charpy impact specimens ($\frac{3}{16}$ x $\frac{3}{16}$ x $1\frac{1}{2}$) exhibited low impact strength as compared with marginal metallic materials. The best titanium carbide base materials produced to date exhibit impact strength somewhere around 5–15 in.-lb. This appears to be inadequate in view of the fact that marginal alloys exhibit an impact strength of about 50–60 in.-lb.

Some additional improvement of titanium carbide base materials seems possible through the proper composition of the binder metal in addition to increasing the amount of the binder metal present in the structure.

Perhaps it will be found that the amount of titanium carbide present in the structure to give the necessary impact resistance will be reduced to around 20–25%. Attempts are being made to produce such a material similar in nature to sintered-aluminum-powder (S.A.P.) type of material. It is reasonable to assume that the type of material that will result from these efforts will be a metal base material rather than a titanium carbide base material.

Fabrication of Titanium Carbide

The third technique employed in attempting to improve the properties of titanium carbide base materials has been the use of such processing techniques as extrusion, casting from the molten state, improvements or modifications in hot-pressing techniques, or in cold-pressing and subsequent sintering techniques.

The work on casting carbides has revealed that it is necessary to reduce the amount of carbide present in the structure to below 50%. The reason for this is that the melt is too viscose and cannot be poured into a suitable mold.

The work on extrusion of powdered materials has progressed far enough to indicate the feasibility of using this technique. The reason for embarking upon this particular investigation was to determine if extrusion would increase the properties of titanium carbide base material by virtue of the fact that the individual particles experience considerable abrasion as the powders are transferred from the holding chamber through an extrusion nozzle. It is believed that this abrasion would tend to destroy surface films of oxygen, thus bringing the particles into more intimate contact with their neighbors and hence better bonding would result. These data should become available within the year (1954).

Other Intermetallic-Type Materials

Boride type materials, although exhibiting extreme brittleness and probably not applicable to jet engine components (blades or buckets), may find application as rocket engine components. It appears that these materials possess higher melting points which may make them more suitable in applications where high temperature erosion is a problem.

Nitride base materials have not appeared too successful in that they have low oxidation resistance. In addition, they are extremely brittle. However, future work might reveal that nitrides in combination with carbides, borides, etc., may produce interesting materials.

Research into the field of aluminide base materials such as molybdenum aluminide or nickel aluminide has revealed that molybdenum aluminide, although possessing some interesting high temperature properties, does not appear to have inherent high strength properties. Its oxidation resistance is good, but it does possess low thermal shock resistance. Fabrication of this material is difficult.

Nickel aluminide, on the other hand, has exhibited good thermal shock resistance, good high temperature oxidation resistance, some room temperature ductility (perhaps forgeable), but its strength is low. Improvement of this material is sought by additions of small amounts of carbides, oxides, or other aluminides. This is an application of the S.A.P. technique.

Recent results obtained on the alumina-chromium type cermet have indicated that when chromium is combined with other metal elements the thermal shock resistance of this body can be improved. These additions to the chromium have resulted in a better "fit" of the thermal expansion properties of the oxide and the metal-binder. Perhaps this technique also accounts for improvement in properties of titanium carbide base materials. When such materials as molybdenum and aluminum are added to nickel they tend to bring the thermal expansion properties of the binder metal into line with the expansion properties of the titanium carbide.

This then would appear to be a fruitful area for research in the improvement of the properties of titanium carbide base materials.

Graphite for High Temperature Applications

The materials discussed up to this point are those which may be considered for the medium temperature range. For extremely high temperature applications such as rocket and ram jet applications the use of graphite is being considered. Successful use of graphite in certain foreign aircraft during World War II, namely the V-2 rockets, is known.

Graphite is an interesting material in that it possesses low specific gravity, high refractoriness, and appears to increase in strength with increasing temperature. The major disadvantage with graphite is that it oxidizes at a relatively low temperature. Some preliminary work on attempting to coat graphite with an oxidation resistant coating has been reasonably successful. The use of a silicide which is painted on the surface of a graphite component and subsequently fired has shown that the surface can be protected against excessive oxidation and the coating produces a reasonably erosion resistant surface.

Work in this area is being expanded. Attempts are being made to improve the properties of graphite. One approach is to coat the surface in a manner similar to that employed with the silicide. In this work, materials are being considered which will combine with graphite to form carbides, thus producing a potentially oxidation resisting surface. In addition to the coating work, we are attempting to form carbon or graphite base materials where graphite will be the major constituent in the structure. There we are thinking of adding metals which form carbides or other carbides, silicides, nitrides, etc.

High temperature oxidation and erosion tests on unprotected graphite have indicated some promise for applications of short-time duration; however, if extended life is to be achieved with the use of graphite base materials, the graphite must be protected in some manner.

Silicon carbide base materials have exhibited good properties for higher temperature applications. Further improvement of these properties is being sought by applying hot-pressing forming techniques and by suitable additions to the composition.

Summary

In summary then, it appears that the major problem facing those attempting to utilize titanium carbide base material and other similar materials in the high temperature areas of aircraft is the problem of impact resistance. Whether this problem can be solved remains to be seen. Considerable skepticism seems to be creeping into the development picture. The S.A.P. approach and attempts to get a better "fit" thermal expansion-wise between the carbide phase and the metal-binder phase appear to be two fruitful areas of investigation for the future.

In considering materials for the extremely high temperature field, graphite appears to be a very promising material. It is certain that an increasing emphasis will be placed on graphite and graphite base materials.

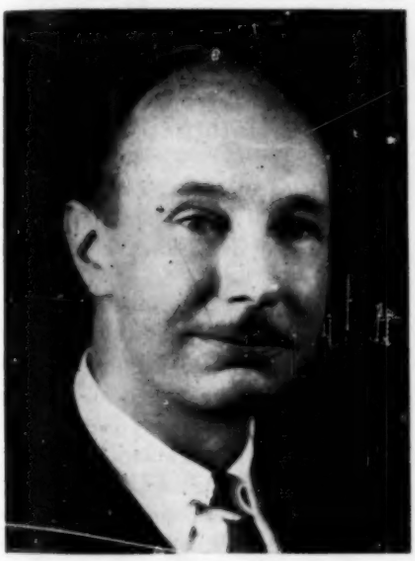
Current Affairs

Candidates for Society Offices—1955-1956

Herbert H. Uhlig

Presidential Candidate

Herbert H. Uhlig has been Vice-President of The Electrochemical Society for the past two and one-half years. Active in the affairs of the Society since 1937 he has served as Chairman of the Corrosion Division, of which he was one of the founders, and the Theoretical Electrochemistry Division, as well as of the Gordon Corrosion Conferences and the Intersociety Corrosion Committee. He is author or coauthor of many papers in the field and is Editor of the "Corrosion Handbook," sponsored by the Corrosion Division of the Society, royalties on which have brought in over $16,000 to the Society. He is past Editor of the JOURNAL.



HERBERT H. UHLIG

Dr. Uhlig received his B.S. degree in chemistry from Brown University in 1929 and his Ph.D. in physical chemistry from Massachusetts Institute of Technology in 1932. After a year of electrochemical research at Rockefeller Institute for Medical Research with Dr. Duncan A. MacInnes, he entered the employ of Lever Brothers Company in Cambridge as research chemist and later Assistant Chief Chemist. The strong attractions of the fundamental sciences led to an appointment in 1936 as research associate in the Corrosion Laboratory at M.I.T. At this time contributions were made to the theory of pitting in stainless steels and the nature of passivity of corrosion resistant alloys. In 1940 he joined the staff of the Research Laboratory of the General Electric Company at Schenectady, and returned to M.I.T. in 1946 where he is presently Professor of Metallurgy, in charge of the Corrosion Laboratory.

Dr. Uhlig's principal researches have been in corrosion and electrochemistry, with particular emphasis on fundamental studies of passivity, metal surface properties, and the chemical and metallurgical behavior of corrosion-resistant alloys.

He is a member of the Advisory Committee for the Prevention of Deterioration Center of the National Research Council. He is also chairman of the organizing committee established recently by the Engineering Foundation to promote and sponsor fundamental research in corrosion and to stimulate the training of men in this field. In March 1951 he received the Willis R. Whitney Award of the National Association of Corrosion Engineers for contributions to the science of corrosion. He is also a member of the American Academy of Arts and Sciences.

William C. Gardiner

Vice-Presidential Candidate

William C. Gardiner was born in Exeter, Ontario, Canada, in 1904 and became a citizen of the United States in 1939. While an undergraduate at Queens University, Professor Dorrance persuaded him that power development on the St. Lawrence River would create a great demand for electrochemists. Accordingly he took a Master's degree working on an electroplating problem. He continued his electrochemical training at Princeton University under Professor G. A. Hulett. His thesis on the Weston Normal Cell was published in the TRANSACTIONS of The Electrochemical Society in 1929 and won for him the Society's first award of the Young Authors' Prize.

Dr. Gardiner spent three years as a Research Chemist for Comstock and Wescott, Inc., in Niagara Falls, working on chlorine metallurgy. Since 1932 he has worked on electrochemical research and development for Mathieson Alkali Works (now Olin Mathieson Chemical Corporation). His present position is Associate Director of Electrochemical Engineering in the Research and Development Division; his work has been with mercury type alkali-chlorine cells.

WILLIAM C. GARDINER

He was active in the design, construction, and initial operation of plants using Mathieson cells at Arvida, Quebec, Saltville, Va., and McIntosh, Ala. He was captain of the U. S. chlorine industry team which toured German chlorine plants after World War II and brought back working drawings and detailed operating instructions of the best practice there. He also worked on the development of a cell to produce magnesium and chlorine from hydrated magnesium chloride feed. These cells were installed at the Mathieson Magnesium Plant in Lake Charles, La., where he was Superintendent of the Electrolytic Department. He holds patents on brine treatment, mercury cells, and magnesium cells and has published papers of interest to the electrolytic chlorine industry. He acts as consultant on electrochemical prob-

FREDERICK A. LOWENHEIM

SHERLOCK SWANN, JR.

LYLE I. GILBERTSON

lems for several U. S. government projects.

Dr. Gardiner joined The Electrochemical Society in 1927 and has been active in the Niagara Falls Section, which he has served as Secretary-Treasurer and Chairman. He also served on convention committees when the Society met in the Buffalo-Niagara Falls area. He has been Chairman of the Industrial Electrolytic Division, and Divisional Editor of the JOURNAL since 1950. He has been on the Alkali-Chlorine Committee twice and gave the Report of this committee at the Chicago Convention as published in the August issue of the Journal.

Frederick A. Lowenheim

Vice-Presidential Candidate

Frederick A. Lowenheim was born in 1909 in New Rochelle, N. Y. After the conventional schooling there he entered Columbia University, where he received his B.A. degree in 1930 and continued to the Doctorate which was completed in 1934 with Professor L. P. Hammett in the field of electrochemistry of nonaqueous solutions. While at Columbia he was active in organizing an undergraduate "chemistry club" and was elected to Phi Lambda Upsilon and Sigma Xi.

In 1936 Dr. Lowenheim joined the Metal & Thermit Corporation as research chemist; he is now Supervisor of Electrochemical Research in the company's Research and Development Laboratories. His principal activity in recent years has been in the field of electrodeposition, with emphasis on the development of new or improved methods of plating tin and its alloys, a field in which several patents have been issued. He has contributed papers on this subject, as well as on the electrodeposition of zirconium metals and the history of electrodeposition, to the TRANSACTIONS of The Electrochemical Society and several trade and technical journals. As visiting lecturer at Stevens Institute of Technology, he teaches advanced inorganic chemistry.

Dr. Lowenheim's activities in The Electrochemical Society have included the chairmanship of the Electrodeposition Division, Metropolitan Section, and Local Section Advisory Committee. He is presently Chairman of the Sustaining Membership Committee and a member of the Ways and Means Committee, as well as a member of various other committees. He has served on the Board of Directors in several capacities. Dr. Lowenheim is also a member of the Editorial Advisory Board and has contributed to The Electrochemical Society Monograph on "Modern Electroplating." He has served as Finance Chairman for three national conventions, two in New York and one in Wrightsville Beach.

Currently he is active in the work of Committee B-8 of the ASTM and is chairman of a working section on tin and tin alloy coatings.

Sherlock Swann Jr.

Vice-Presidential Candidate

Sherlock Swann, Jr., is currently Divisional Editor on the JOURNAL for the Electro-Organic Division, and is serving on the Acheson Award Committee.

During his membership in the Society, which began in 1928, Dr. Swann has held many offices and devoted much time to the various interests of the Society. Included in the offices he held are: Manager from 1934 to 1940; Vice-President from 1941 to 1943; and again Manager from 1943 to 1946. He has also been prominent in the Electro-Organic Division of the Society, of which he was Secretary-Treasurer from 1940 to 1942; Vice-Chairman, 1942 to 1944; and Chairman from 1944 to 1946; and has served on many committees.

Dr. Swann was born in Baltimore, Md., and received his B.S. degree from Princeton University in 1922, and his Ph.D. degree in organic chemistry from Johns Hopkins University in 1926. The following year he became a member of the Division of Chemical Engineering, Engineering Experiment Station, University of Illinois, and has been Research Professor of Chemical Engineering at that University since 1941. His principal research is in the field of electro-organic chemistry. He is the author of a number of papers in the TRANSACTIONS and JOURNAL of the Society and of a chapter in "Catalytic, Photochemical, and Electrolytic Reactions," edited by Arnold Weissberger, Interscience Publishers, New York (1948).

Lyle I. Gilbertson

Candidate for Treasure

Lyle I. Gilbertson, Director of the Murray Hill Laboratories of Air Reduction Company, Inc., Murray Hill, N. J., was born in 1903 near Beloit, Wis. A graduate in chemistry of Augustana College in 1925, he received the M.A. degree the following year from the University of Wisconsin and in 1940 the Ph.D. degree in inorganic chemistry from Indiana University.

After a year as instructor at Carleton College, Northfield, Minn., in 1926–1927, he was a member of the staff of the Department of Chemistry and Chemical Engineering of the State College of Washington until he joined the Division of War Research at Columbia University in 1942. Later he was affiliated with the Manhattan Project and in 1946 he joined the research staff of the Air Reduction Company.

Dr. Gilbertson's research activities have been largely in the field of inorganic chemistry. In addition, he worked for a period of time on problems of electrodeposition of silver, which work was begun at Indiana University as a student of Professor Frank C. Mathers. He has contributed papers on electrodeposition to the TRANSACTIONS of The Electrochemical Society and to other publications in the fields of selenium and tellurium chemistry.

As a member of The Electrochemical Society since 1935, Dr. Gilbertson's activities have included the chairmanship of the New York Metropolitan Section and, since 1950, the chairmanship of the Membership Committee and membership in the Admissions Committee. He is also a member of Phi Lambda Upsilon, Sigma Xi, Alpha Chi Sigma, New York Academy of Sciences, American Institute of Chemists, and the American Chemical Society.

Program for the Boston Meeting

All arrangements have been completed for the Society's fall meeting at Boston, Massachusetts, October 3-7, with headquarters at the Hotel Statler, Park Square, Boston.

The formal opening of the convention will take place on Monday, October 4, at 9:00 A.M., with the start of the technical sessions.

On Sunday a meeting of the Ways and Means Committee will be held at 10:00 A.M., and the Board of Directors Meeting at 2:30 P.M.

Members should consult their program booklets for details of social activities, committee meetings, divisional luncheons, etc. The schedule of Plant Trips and the Technical Program appear below.

Plant Trips

Several plant trips have been arranged to supplement the technical program.

On Monday afternoon trips are planned to Ionics, Inc., and Arthur D. Little, Inc. At the Ionics plant there will be a demonstration of an electric membrane demineralizer developed for the treatment of naturally occurring saline waters and other mineral containing solutions by the use of electricity in conjunction with novel selectively conductive membranes. At Arthur D. Little there will be a tour of this consulting company's new Acorn Park research and development laboratory, which is outstanding as an example of low cost but high utility laboratory construction. This will be followed by refreshments and discussion of an operations research study of a corrosion problem in the chemical industry.

Tuesday morning an inspection of the Watertown Arsenal's large plating shop and plating laboratory will be followed by a presentation of the work the Arsenal is doing in high vacuum metallurgy using the vacuum fusion apparatus and the mass spectrometer. (Only U. S. citizens are permitted to visit the Arsenal.)

Wednesday afternoon a trip is planned to the M.I.T. Corrosion Laboratory, of which Dr. H. H. Uhlig is Head, and to the Computer Laboratory where the "Whirlwind" digital computer will be featured.

Technical Program

Monday, October 4, 1954

9:00 A.M.—Formal Opening of the 106th Convention, with Introduction by General Chairman S. E. Eaton and response by President Marvin J. Udy.

Battery—Theoretical Electrochemistry Joint Symposium

Monday, October 4, 1954

Basic Electrode Processes with George W. Heise presiding

9:15 A.M.—"Electrode Kinetics in Relation to Battery Processes" by Ernest Yeager, Dept. of Chemistry, Western Reserve University, Cleveland, Ohio.

9:45 A.M.—"Thermodynamics of Electrochemical Cells" by Walter J. Hamer, National Bureau of Standards, Washington, D. C.

10:15 A.M.—"Mass Transfer in Electrode Reactions" by Carl Wagner, Dept. of Metallurgy, Massachusetts Institute of Technology, Cambridge, Mass.

11:00 A.M.—"Rate of Reaction between a Porous Solid and a Fluid Component with Diffusion Controlling" by Howard J. Strauss, Electric Storage Battery Co., Philadelphia Pa.

11:30 A.M.—"Behavior of Interstitial Solutes in the Transition Metals" by R. S. Dean and W. W. Gullett, Chicago Development Corp., Riverdale, Md.

Battery—Theoretical Electrochemistry

Joint Symposium (cont'd)

Cathode Processes with Oliver W. Storey presiding

2:00 P.M.—"Cathode Processes in Electrochemical Cells" by E. Willihnganz, Gould-National Batteries, Inc., Depew, N. Y.

2:30 P.M.—"The Electrochemistry of Manganese Dioxide" by W. C. Vosburgh, Dept. of Chemistry, Duke University, Durham, N. C.

3:00 P.M.—"A Further Study of Electrodeposited Manganese Dioxide Electrodes" by W. C. Vosburgh, Richard S. Johnson, John S. Reiser, and Douglas R. Allenson, Dept. of Chemistry, Duke University, Durham, N. C.

3:30 P.M.—"Formation of Manganese (II) Ion in the Discharge of the Manganese Dioxide Electrode" by A. M. Chreitzberg, Jr., Douglas R. Allenson, and W. C. Vosburgh, Dept. of Chemistry, Duke University, Durham, N. C.

4:00 P.M.—"The Overpotential of the Manganese Dioxide Electrode" by A. M. Chreitzberg, Jr., and W. C. Vosburgh, Dept. of Chemistry, Duke University, Durham, N. C.

4:30 P.M.—"Cathode Reactions of the Leclanché Dry Cell" by N. C. Cahoon, R. S. Johnson, and M. P. Korver, National Carbon Research Labs., Cleveland, Ohio.

Battery—Theoretical Electrochemistry

Joint Symposium (cont'd)

Tuesday, October 5, 1954

Cell Processes with C. C. Rose presiding

9:00 A.M.—"Lead Dioxide Reactions in the Storage Battery" by E. Willihnganz, Gould-National Batteries, Inc., Depew, N. Y.

9:25 A.M.—"Influence of Metallic Additions upon Lead Acid Storage Battery Performance" by Bernard Agruss, Research Labs., National Lead Co., Brooklyn, N. Y.

9:50 A.M.—"Lead Storage Battery Performance in Car Service" by Dudley Haskell, W. P. Fuller & Co., South San Francisco, Calif.

10:15 A.M.—"Lead Acid Storage Batteries—Barium Sulfate as a Positive Plate Contaminant" by J. F. Dittmann and H. R. Harner, Eagle-Picher Co., Joplin, Mo.

10:40 A.M.—"Determination of the Internal Resistance of Lead-Acid Storage Cells" by J. J. Lander and E. E. Nelson, Naval Research Lab., Washington, D. C.

11:05 A.M.—"Resistance and Polarization in the Storage Battery by A-C Bridge Methods" by E. Willihnganz, Gould-National Batteries, Inc., Depew, N. Y.

11:30 A.M.—"The Internal Resistance of Primary and Secondary Batteries and Its Determination" by C. R. G. Drotschmann, Wetenschappelijk en Technisch Research en derzelver Exploitatie, Utrecht, Holland.

Battery—Theoretical Electrochemistry

Joint Symposium (cont'd)

Cell Processes (cont'd)
with Ernest Yeager presiding

2:00 P.M.—"Resistance Studies on Various Types of Dry Cells" by Richard Glicksman and C. K. Morehouse, RCA Research Labs., Princeton, N. J.

2:25 P.M.—"Reactions at Metallic Anodes in Primary and Secondary Cells: A Review" by N. C. Cahoon, National Carbon Research Labs., Cleveland, Ohio.

2:55 P.M.—"Reactions in the Air Depolarized Cell: A Review" by E. A. Schumacher, National Carbon Research Labs., Cleveland, Ohio.

3:25 P.M.—"Anodic Corrosion of Zinc in Alkali" by T. P. Dirkse, Calvin College, Grand Rapids, Mich.

3:50 P.M.—"Theoretical Standard Electromotive Forces for Cells Containing a Single Solid or Molten Halide Electrolyte" by Walter J. Hamer, Marjorie S. Malmberg, and Bernard Rubin, National Bureau of Standards, Washington, D. C.

4:15 P.M.—"Nuclear Batteries" by William Shorr, Signal Corps Engineering Labs., Ft. Monmouth, N. J.

Battery

Wednesday, October 6, 1954

Technology of Batteries
with E. Willihnganz presiding

9:00 A.M.—"A Method of Plastic Impregnation for the Investigation of Storage Battery Failure" by A. C. Simon and E. L. Jones, Naval Research Lab., Washington, D. C.

9:25 A.M.—"Further Studies on the Anodic Corrosion of Lead in Sulfuric Acid Solutions" by J. J. Lander, Naval Research Lab., Washington, D. C.

9:50 A.M.—"Anodization of Lead in Sulfuric Acid" by Jeanne Burbank, Naval Research Lab., Washington, D. C.

10:15 A.M.—"Rapid Corrodibility Evaluation of Lead-Acid Storage Cell Positive Grid Alloys" by James F. McGivern, Jr., Metallurgical Research Lab., Electric Storage Battery Co., Philadelphia, Pa.

10:40 A.M.—"A Rapid Test for Sulfation" by C. C. Rose, Willard Storage Battery Co., Cleveland, Ohio.

11:05 A.M.—"Role of Inverse Segregation and Redistribution of Solute Atoms in the Freezing of Hypoeutectic Lead-Antimony Alloys" by A. C. Simon and E. L. Jones, Naval Research Lab., Washington, D. C.

11:30 A.M.—"Color Changes in Lead Oxides with Changes in Temperature" by Everett J. Ritchie and Paul E. Jensen, Eagle-Picher Research Labs., Joplin, Mo.

Battery

Technology of Batteries (cont'd)
with Everett J. Ritchie presiding

2:00 P.M.—"Sealed Nickel-Cadmium Cells" by Ernst G. Baars, Signal Corps Engineering Labs., Ft. Monmouth, N. J.

2:25 P.M.—"Gassing of Dry Cells" by Earl Otto and Woodward G. Eicke, Jr., National Bureau of Standards, Washington, D. C.

2:50 P.M.—"Effect of Low Temperature Storage upon the Shelf-Life Characteristics of Dry Batteries" by Charles H. Clark, Signal Corps Engineering Labs., Ft. Monmouth, N. J.

3:15 P.M.—"A Film Lining for High Capacity Dry Cells" by N. C. Cahoon and M. P. Korver, National Carbon Research Labs., Cleveland, Ohio.

3:40 P.M.—"Effect of High Temperature Storage on the Stability of Battery-Grade Manganese Dioxide" by Arthur F. Daniel, Signal Corps Engineering Labs., Ft. Monmouth, N. J.

Corrosion

Monday, October 4, 1954

Symposium on Stress Corrosion Phenomena
with W. D. Robertson presiding

2:00 P.M.—"Introductory Review of the Problem" by J. J. Harwood, Office of Naval Research, Washington, D. C.

2:45 P.M.—"Fracture Mechanics" by E. Orowan, Massachusetts Institute of Technology, Cambridge, Mass.

3:30 P.M.—"Crystallography and Corrosion Cracking" by W. D. Robertson, Dept. of Metallurgy, Hammond Metallurgical Lab., Yale University, New Haven, Conn.

4:15 P.M.—"Stress Corrosion of Homogeneous Alloys" by L. Graf, Max-Planck Institute fur Metallforschung, Stuttgart, Germany.

Corrosion

Tuesday, October 5, 1954

Symposium on Stress Corrosion Phenomena (cont'd)
with Raymond B. Hoxeng presiding

9:00 A.M.—"Grain Boundary Structure" by Bruce Chalmers, Harvard University, Cambridge, Mass.

9:45 A.M.—"Metallurgical Aspects of Stress Corrosion in Aluminum Alloys" by E. C. W. Perryman, Aluminium Laboratories Ltd., Kingston, Ont., Canada.

10:30 A.M.—"Role of Surface Adsorption of Solute Atoms in Stress Corrosion of Alloys" by Rudolph Speiser and J. W. Spretnak, Dept. of Metallurgy, Ohio State University, Columbus, Ohio.

11:15 A.M.—"Stress Corrosion of Austenitic Stainless Steel" by C. Edeleanu, Brown-Firth Research Labs., Sheffield, England.

Corrosion

Symposium on Stress Corrosion Phenomena (cont'd)
with T. P. May presiding

2:00 P.M.—"Occlusion of Hydrogen in Iron and Its Alloys" by W. R. Heller, Shell Development Co., Emeryville, Calif.

2:45 P.M.—"Hydrogen Embrittlement" by W. M. Baldwin, Case Institute of Technology, Cleveland, Ohio

3:30 P.M.—"Caustic and Nitrate Cracking of Steel" by R. N. Parkins, University of Durham, Newcastle-upon-Tyne, England.

4:15 P.M.—"Laboratory Investigation Techniques Relating to Stress Corrosion Cracking" by H. R. Copson, Research Lab., International Nickel Co., Inc., Bayonne, N. J.

Corrosion (cont'd)

Wednesday, October 6, 1954
with J. V. Petrocelli presiding

9:00 A.M.—"An Interpretation of the Significance of the Potentials of Passive Iron" by M. J. Pryor, Dept. of Metallurgical Research, Kaiser Aluminum & Chemical Corp., Spokane, Wash.

9:30 A.M.—"Electrochemical Behavior of Iron in Oxygen Free Acid Environments" by Milton Stern and Herbert H. Uhlig, Corrosion Lab., Dept. of Metallurgy, Massachusetts Institute of Technology, Cambridge, Mass.

10:00 A.M.—"Nature of Film on Iron Passivated by Nitric Acid" by Herbert H. Uhlig and Thomas L. O'Connor, Corrosion Lab., Dept. of Metallurgy, Massachusetts Institute of Technology, Cambridge, Mass.

10:30 A.M.—"Corrosion Inhibitors and Polarographic Maxima" by Harry C. Gatos, Engineering Research Lab., Engineering Dept., E. I. du Pont de Nemours & Co., Inc., Wilmington, Del.

11:00 A.M.—"A Theoretical Basis for a New Method of Investigating Corrosion Inhibition" by J. G. Jewell, Gulf Research & Development Co., Pittsburgh, Pa.

11:30 A.M.—"Effect of Oxygen, Chlorides, and Calcium Ion on Corrosion Inhibition of Iron by Polyphosphates" by Herbert H. Uhlig, D. N. Triadis, and Milton Stern, Corrosion Lab., Dept. of Metallurgy, Massachusetts Institute of Technology, Cambridge, Mass.

Corrosion (cont'd)

with Harry C. Gatos presiding

2:00 P.M.—"Contribution to the Theory of Electropolishing" by Carl Wagner, Dept. of Metallurgy, Massachusetts Institute of Technology, Cambridge, Mass.

2:30 P.M.—"The Mechanism of Metallographic Etching, I. Reaction Potentials of a Two-Phase Brass in Various Etching Reagents" by George L. Kehl and Max Metlay, School of Mines, Columbia University, New York, N. Y.

3:00 P.M.—"The Mechanism of Metallographic Etching, II. Current-Potential Relationships during Etching of a Two-Phase Brass in Various Reagents" by Max Metlay and George L. Kehl, School of Mines, Columbia University, New York, N. Y.

3:30 P.M.—"Crystallographic Dependence of the Oxidation Potential of Copper" by W. E. Tragert and W. D. Robertson, Dept. of Metallurgy, Hammond Metallurgical Lab., Yale University, New Haven, Conn.

4:00 P.M.—"The Formation of Anodic Oxide Films on Cathodes" by D. A. Vermilyea, Research Lab., General Electric Co., Schenectady, N. Y.

4:30 P.M.—"Fundamental Thermodynamics and Kinetics of Electrode Processes" by Pierre Van Rysselberghe, Dept. of Chemistry, University of Oregon, Eugene, Oreg.

4:45 P.M.—"Corrosion Inhibition and Cathodic Protection Examined from the Point of View of the Thermodynamics of Irreversible Processes" by Pierre Van Rysselberghe, Dept. of Chemistry, University of Oregon, Eugene, Oreg.

5:00 P.M.—"Codeposition Examined from the Point of View of the Thermodynamics of Irreversible Processes" by Pierre Van Rysselberghe, Dept. of Chemistry, University of Oregon, Eugene, Oreg.

Corrosion (cont'd)
Thursday, October 7, 1954
with C. V. King presiding

9:00 A.M.—"The Isolation of Surface Films from Aluminum and Its Alloys" by M. J. Pryor and D. S. Keir, Dept. of Metallurgical Research, Kaiser Aluminum & Chemical Corp., Spokane, Wash.

9:25 A.M.—"The Anodic Treatment of Aluminum in Sulfuric Acid Solutions" by Roy C. Spooner, Aluminium Laboratories Ltd., Kingston, Ont.

9:50 A.M.—"Depolarized Dissolution of Iron in Acid Solution, I. Potential-Current Density Relationships" by A. C. Makrides, N. M. Komodromos, and Norman Hackerman, Dept. of Chemistry, University of Texas, Austin, Texas.

10:15 A.M.—"Stainless Steel in Ferric Chloride Solution. Exploratory Experiments" by Herman A. Liebhafsky and Arthur E. Newkirk, Research Lab., General Electric Co., Schenectady, N. Y.

10:40 A.M.—"Kinetics of the Corrosion of Copper in Acid Solutions" by John R. Weeks and George R. Hill, Institute for the Study of Rate Processes, University of Utah, Salt Lake City, Utah.

11:05 A.M.—"The Difference Effect on Aluminum Dissolving in Hydrofluoric and Hydrochloric Acids" by M. E. Straumanis and Y. N. Wang, Dept. of Metallurgy, School of Mines and Metallurgy, University of Missouri, Rolla, Mo.

11:30 A.M.—"The Corrosion of Aluminum in Potassium Chloride Solutions" by W. Beck, F. G. Keihn, and R. G. Gold, Lehigh University, Bethlehem, Pa.

Corrosion (cont'd)
with W. D. Robertson presiding

2:00 P.M.—"The Oxidation of Iron-Molybdenum Alloys" by S. S. Brenner, Research Lab., General Electric Co., Schenectady, N. Y.

2:30 P.M.—"The Oxidation of Nickel-Molybdenum Alloys" by S. S. Brenner, Research Lab., General Electric Co., Schenectady, N. Y.

3:00 P.M.—"The Catastrophic Oxidation of Some Molybdenum Containing Alloys" by S. S. Brenner, Research Lab., General Electric Co., Schenectady, N. Y.

3:30 P.M.—"Kinetics of the Reaction of Hydrogen with Zirconium" by Jack Belle, B. B. Cleland, and M. W. Mallett, Battelle Memorial Institute, Columbus, Ohio.

4:00 P.M.—"Kinetics of the High Temperature Oxidation of Zirconium" by Jack Belle and M. W. Mallett, Battelle Memorial Institute, Columbus, Ohio.

Electrodeposition

Monday, October 4, 1954
with C. A. Snavely presiding

9:15 A.M.—"Brightening Agents for the Tin-II Sulfate-Sulfuric Acid Electrolyte" by C. A. Discher and F. C. Mathers, Indiana University, Bloomington, Ind.

9:40 A.M.—"Electrodeposition of Lead from Lead Phenol Sulfonate Solutions" by F. C. Mathers and Harry C. Gatos, Indiana University, Bloomington, Ind.

10:05 A.M.—"Electrodeposition of Rhodium" by Edward A. Parker, Technic Inc., Providence, R. I.

10:30 A.M.—"Electroless Nickel Plating of Internal Aluminum Surfaces" by P. H. Eisenberg and H. I. Raiklen, Atomic Energy Div., Sylvania Electric Products Inc., Bayside, N. Y.

10:55 A.M.—"Zincaloy—A New Solderable Zinc Alloy Plating Process" by E. B. Saubestre, Physics Labs., Sylvania Electric Products Inc., Bayside, N. Y.

11:20 A.M.—"Use of a Fractional Factorial Experiment to Study a Manganese-Tin Alloy Plating Bath" by W. C. Schickner and A. B. Tripler, Jr., Battelle Memorial Institute, Columbus, Ohio.

Electrodeposition (cont'd)
with C. A. Snavely presiding

2:00 P.M.—"Electrodeposition of Nickel at a Mercury Cathode" by J. T. Funkhouser and L. B. Rogers, Dept. of Chemistry and Lab. of Nuclear Science, Massachusetts Institute of Technology, Cambridge, Mass.

2:25 P.M.—"Separations with a Mercury Electrode. Determination of Certain Metallic Impurities in Vanadium Salts" by William E. Schmidt and Clark E. Bricker, Princeton University, Princeton, N. J.

2:50 P.M.—"Effect of Temperature Changes on the Polarographic Waves of Thallous, Cadmium, and Cobaltous Ions" by J. F. Murphy, Dept. of Metallurgical Research, Kaiser Aluminum & Chemical Corp., Spokane, Wash.

3:25 P.M.—"Permeation of Gases through Electrolytic Nickel Deposits, I. Determination of the Intrinsic Permeability of Nickel Deposits to Gases" by D. T. Ewing and J. Martin Tobin, Michigan State College, East Lansing, Mich., and D. Gardiner Foulke, Hanson-Van Winkle-Munning Co., Matawan, N. J.

3:50 P.M.—"Permeation of Gases through Electrolytic Nickel Deposits, II. Determination of the Effect of Several Variables upon the Intrinsic Permeability of Nickel Deposits to Gases" by D. T. Ewing and J. Martin Tobin, Michigan State College, East Lansing, Mich., and D. Gardiner Foulke, Hanson-Van Winkle-Munning Co., Matawan, N. J.

4:15 P.M.—"Production of High-Purity Cobalt" by K. K. Kershner, F. W. Hoertel, and J. C. Stahl, Bureau of Mines, U. S. Dept. of the Interior, Rolla, Mo.

Electrodeposition (cont'd)

Tuesday, October 5, 1954

Theory of Electrodeposition
with M. L. Holt presiding

9:00 A.M.—"Catalysis of Electron Transfer Reactions" by J. F. Murphy, Dept. of Metallurgical Research, Kaiser Aluminum & Chemical Corp., Spokane, Wash.

9:25 A.M.—"A Theory of Chromium Plating from Chromic Acid Solution Based on Dynamic Cell Measurements" by Arthur A. Burr, Dept. of Metallurgical Engineering, Rensselaer Polytechnic Institute, Troy, N. Y.

9:50 A.M.—"Mass Spectrometric Examination of Hydrogen in Chromium Plated Steel" by Charles Levy and George A. Consolazio, Watertown Arsenal Lab., Watertown, Mass.

10:15 A.M.—"Influence of the Transference Number in Plating from Anionic Complexes" by Frederick A. Lowenheim, Metal & Thermit Corp., Rahway, N. J.

10:40 A.M.—"Electrodeposition of Nickel" by J. P. R. Cels, Ernest Yeager, and Frank Hovorka, Dept. of Chemistry, Western Reserve University, Cleveland, Ohio.

11:05 A.M.—"Effect of Some Externally Imposed Factors on the Crystal Orientation in Electrodeposited Metals—High Speed Rotation of Cathode and Presence of a Magnetic Field" by Ling Yang, Metals Research Lab., Carnegie Institute of Technology, Pittsburgh, Pa.

11:30 A.M.—"Polarography of Indium and Its Application" by G. H. Turner and J. A. Brown, Consolidated Mining and Smelting Co. of Canada Ltd., Trail, B. C.

11:45 A.M.—"An Electrical Phenomenon at Interfaces" by Joseph G. Barredo, Instituto de Quimica-Fisica Rocasolano, Consejo Superior de Investigaciones Cientificas, Madrid, Spain.

Electrodeposition (cont'd)

Electrodeposition from Nonaqueous Media
with M. L. Holt presiding

2:00 P.M.—"Electrodeposition of Metals from Organic Solutions, I. Introduction" by Abner Brenner, National Bureau of Standards, Washington, D. C.

2:20 P.M.—"Electrodeposition of Metals from Organic Solutions, II Further Studies on the Electrodeposition of Aluminum from the Hydride Type Bath" by Jean Connor, National Bureau of Standards, Washington, D. C.

2:40 P.M.—"Electrodeposition of Metals from Organic Solutions, III. Electrodeposition of Titanium- and Zirconium-Aluminum Alloys" by Walter E. Reid, Jr., National Bureau of Standards, Washington, D. C.

3:00 P.M.—"Electrodeposition of Metals from Organic Solutions, IV. Electrodeposition of Beryllium and Beryllium Alloys" by Gwendolyn B. Wood, National Bureau of Standards, Washington, D. C.

3:30 P.M.—"Electrolytic Production of Coatings on Molybdenum from Fused Salts" by W. Beck and M. Ford, American Electro Metal Corp., Yonkers, N. Y.

4:00 P.M.—"Electrodeposition of Bismuth" by Kelso B. Morris, Dolores Z. Douglass, and Clarence B. Vaughn, Dept. of Chemistry, Howard University, Washington, D. C.

Electrothermics and Metallurgy

Wednesday, October 6, 1954

Round-Table Discussion
Safety in Handling Zirconium Powder
with W. M. Raynor presiding

9:15 A.M.–11:30 A.M.—Round-table discussion presented by the Society's Committee for the Safe Handling of Zirconium Powder.

Part I—Members of the Committee will present briefly their experiences with zirconium powder to illustrate and explain the hazards involved in the handling of the metal.

Part II—Data sheet recommending what are considered the safest methods for the handling and packaging of zirconium powder will be presented.

Part III—Open discussion.

Electrothermics and Metallurgy (cont'd)
with J. M. Blocher, Jr., presiding

2:00 P.M.—Keynote address—"The Bright Spark in the Metals Industry" by James D. Nisbet, Universal-Cyclops Steel Corp., Bridgeville, Pa.

2:25 P.M.—"Arc Melting in High Vacuum" by P. C. Rossin, Metallurgy Research Dept., General Electric Co., Schenectady, N. Y.

2:50 P.M.—"Vacuum Melting of High-Alloy Materials" by Howard R. Spendelow, Jr., and I. S. Servi, Metals Research Labs., Electro Metallurgical Co., New York, N. Y., and Glenn Fritzlen, Haynes Stellite Div., Union Carbide and Carbon Corp., Kokomo, Ind.

3:15 P.M.—"Impact Properties of Vacuum Melted Iron-Chromium Alloys" by J. L. Ham and F. L. Carr,

Feature Section

The Role of Science and Technology in Education[1]

John T. Rettaliata[2]

Re-evaluation of Education

In a democracy, there can never be too much discussion and examination of the basic constituents of our way of life. We must continually evaluate and re-evaluate our institutions, honestly and with a critical eye, if they are to remain vigorous and meaningful.

Certainly, education is no exception. Indeed, education in many ways is the foundation of our democracy and its central pillar. Without it, the stirring words of Carlisle Pitt, and Voltaire would not have spread across the seas to plant the hunger for liberty and equality in the souls of men and women in the American colonies and eventually in almost every other corner of the world.

Without education today, the flame these men and women so carefully fed and preserved for us would be lost to our children. Without education, our generation would not know the relative freedom from grinding physical toil that was the lot of most of our forebears. Without education, succeeding generations would be unable to profit from our failures and triumphs.

It is well, then, that we look critically at education and try to see in what ways it is or is not serving us and our democracy as it should.

Representing, as I do, an institution that is known primarily as a technological institution, I am going to discuss the place of science and technology in American education today.

Science and technology must be made an integral part of education in America, from grammar school up. We live in a world of technology, and we should be guilty of gross unrealism if we ignored that fact in any part of our educational programs.

Our entire lives are intricately involved in technology. Many of us find employment in industries and businesses that were unknown not too long ago. Where did they come from? You know the answer as well as I do—from our continually advancing technological skills.

Never before in all history has technology played so vital a part in the lives of men and women everywhere. Never before have so many persons, especially in this country, encountered in their everyday lives so many miracles of production and design—miracles that they have come to accept as a commonplace part of existence.

That is why I feel strongly that knowledge of science and technology and their places in our economy must be integrated into our educational programs. If we do not learn to understand our own developments, how can we learn to manage them so that they will serve rather than destroy us? If we honestly hope to minimize poverty in our land and open up broad new avenues of opportunity and advancement for all people, how can we do anything else but continue a course that already has given us a standard of living unparalleled in the history of the world?

One fact is inescapable: technology is the keystone of our great economy. New products, new production processes are continually springing from our vast storehouse of technological know-how.

But this know-how does not perpetuate itself, any more than other worthwhile achievements do. It must be preserved in our educational institutions and there transmitted to the youth of our nation.

Functions of Education

These educational institutions, of course, serve other functions than merely passing on certain bodies of knowledge.

First, they continually increase mankind's store of knowledge. The backgrounds of most of the product and process inventions that underlie our modern world originated in the laboratories of universities around the world. At this very moment lights are burning late in laboratories, and new generations of men and women are grappling with problems the answers to which will constitute tomorrow's technology.

Second, it is the duty of our educational institutions to be concerned with the great responsibilities that go with great achievements. Technology has placed tremendous economic and military power in our hands. The extent to which we misuse that power represents, in large measure, the extent to which we are unprepared for it. If succeeding generations are to do better than we have done, it is our urgent business to educate them now for life in the kind of world where atomic energy and jet airplanes are commonplace.

I am sorry to say that, so far, we have made little progress in this direction. We are dealing with a relatively new concept when we speak of teaching responsibility for the consequences of our vast strides in material knowledge.

In the past, the university has generally provided a cloistered atmosphere. The ideal was for men to withdraw from active life so they could meditate and study. There was little opportunity for contact with the market place, and little opportunity for the market place to influence what was being taught within the ivory towers.

Even in American colleges this had usually been the common pattern for more than two hundred years. It still is a factor in American higher education.

But powerful forces have been at work, forces that have made inevitable a closer contact between the university, the

[1] This paper was prepared for delivery before the Electric Insulation Symposium at the Chicago Meeting, May 3, 1954.

[2] President, Illinois Institute of Technology, Chicago, Illinois.

market, the factory, and the farm. Perhaps the most important of these forces is the change in our way of living. It is largely as we have become a nation of cities that the necessity for partnership between education and industry has arisen.

We live in larger social units than our grandfathers did. Each segment of these large urban centers is dependent on other segments. What one part does or fails to do has a far-reaching effect on every other part.

It is the recognition of this interdependence by educators, industrialists, and businessmen that leads them to explore new and better ways of directing education and using the fruits of education for the greater good of all our people rather than the private gain of a few.

I consider it vitally important that they continue to do so, for lack of harmony and understanding between groups robs our material developments of much of their potential for good.

Need for Understanding

Lack of understanding is the basis of our present international tensions. It stands between us and the achievement of security, both economic and military.

It is at the root of our labor-management troubles; to some extent, it exists even on the university campus.

With America's entry into a technological era, both education and industry have undergone great change. Year after year, the demand has been for larger and larger facilities in science and engineering.

Universities have responded wholeheartedly to this demand, and in doing so they have to a large degree forsaken the cloistered way of life and come forth to meet the needs of industry in technological education and research.

And yet they have tended to become divided into two groups. On one side are those in the technological field, with their emphasis on measurable quantities. On the other side are those in the humanities and social sciences, whose interests are centered on ethical and cultural standards.

As each group became more firmly established, it came to have less and less contact with the other and consequently less understanding of the other.

I know that the technological institutions at one time tended to develop too narrow a view and to overlook social considerations. I am glad to say that this shortcoming has been largely corrected. Today there are definite programs for broadening the educational backgrounds of scientists and engineers. In line with that trend, Illinois Institute of Technology has modified its curriculum to give its students more economics, more history, more sociology, along with their technological studies.

Now let's look at the other side of the educational picture. How broad a view do students in the schools that emphasize the humanities and social sciences have of scientific and technological developments?

I am afraid that in many of their curricula the part technology plays in our lives is too often overlooked. I hope that those institutions will take steps to correct these shortcomings where they exist in their programs, even as we in the technological schools are striving to give our students a better balanced program.

I don't say that everyone should be an engineer or a scientist, even though it may sometimes seem to us that a thorough technical training is essential in a world of television sets, hydraulic brakes, and helicopters. Housewives, for example, with vacuum cleaners, dishwashers, washing machines, and other conveniences, probably operate more electrical and mechanical equipment in the course of a day's work than a master mechanic did a generation ago. Be that as it may, I'm not going to recommend that a woman be required to present an engineering diploma when she applies for a marriage license.

Scientific and technological pursuits in themselves are still specializations, and no one can specialize in everything. Persons trained and experienced in other occupations will still be needed, as they always have been needed. But those who teach our children, manage our businesses, edit our newspapers, and run our factories should have some knowledge of the productive technology that makes our economy function.

Technology, applied to American industry, business, and agriculture, has created leisure time and material comforts that exceed the wildest dreams of anyone who lived a century ago.

The paradox of our time is that despite this progress we still find ourselves uneasy, dissatisfied, uncertain of the future. We face grave and trying problems at home and in many parts of the world.

Technology Develops Fears

Different persons blame this state of affairs on different causes. But underneath it all, it seems to me, is a misunderstanding of the role of technology in modern life.

Because of this misunderstanding we are surrounded by doubt and fear—fear of the machine, fear of change, fear of technological unemployment, fear of domination by large corporations.

These fears arise because technology is not well enough understood by the man and woman in the street. Particularly mysterious to them are the ways in which modern technical processes are brought into being and their products made available to the public. Let us examine this process briefly.

A technical development may have its beginning in a laboratory, but it benefits mankind only when it is taken out of the laboratory to serve some useful and constructive purpose.

This requires a financial risk, in many cases a very large financial risk. Thus, in our country, technological innovations reach the public through the medium of industry and business.

When we praise American technology for the wonders it has produced, we must also praise American business and industry. Neither could exist as we know it without the other. To praise technology and condemn industry is like praising milk but condemning cows. Yet there are those who manage to perform this trick of logic.

We must overcome our fear of technology. We can do so by the time-tried method of investigating it and its effects. Ignorance is the basis of most fears; it is the basis of this fear, too.

As important as facing up to the role of technology ourselves is our obligation to embrace it in our schools even as we teach history, philosophy, and the other cultural heritages that make our society what it is.

If we do this, we will not be a nation of people haunted by the fear that technology will cost us our jobs or bring about other unhappy consequences. We will see that even though the buggy-whip factory is extinct, we can get along without it in a society that employs 12,000,000 persons to make and service its automobiles.

Today our colleges and universities belong in the forefront

of a vigorous campaign to dispel the confusion that exists regarding technological development.

One effective way in which they could do this is by widening the base of both scientific and liberal arts curricula. Many are already doing so, but there is room for improvement.

In this technological age, of which every one of us is a part, it does not seem unreasonable to require each of our students in the arts and social sciences to have some background of technical study, at least enough so he can understand our dependence on technical advances.

When this is a part of his background and when, at the same time, the student of technology has a good grounding in the humanities and social sciences, I believe we shall produce generations of men and women far more capable of guiding their destinies than our generation has been. If it is true that we cannot ignore the past, it is just as true that misjudging technology amounts to turning our backs on the present and future.

The schools of technology must not overlook the lessons to be learned from evaluating the human and spiritual aspects of our civilization. Those in the fields of the humanities must have a basic understanding and appreciation of the part advancing technology is playing in the development of our nation if they are to contribute intelligently to the life of the nation.

Technology, fostered by our free institutions, has enabled us in America to build rapidly and well. Our maze of modern industry is only the superficial evidence of that building.

Increasing amounts of leisure time and increasingly higher standards of living have enabled our people to be schooled as no other people has ever been schooled, and knowledge begets the thirst for new knowledge.

We are a people who have been taught to aspire to better things that make life more exciting, more productive, more worth living, than it was in the past.

We have trained men and women alike to throw open closed doors, until it is a national doctrine that no threshold is uncrossable. We dare to believe that even the distant frontiers of other worlds will be crossed tomorrow.

We must not dwell too long on what has been done, impressive as that is. Our teachers and our students think more of what is waiting to be done.

We Americans number about 160 million persons today. Serving the 200 millions expected before the end of the century will demand the vast expansion of everything we have today in the United States.

From a technological point of view, such an expanded population will surely demand the opening up of untapped resources, the salvaging of natural treasures now buried deep in the oceans and seas. Such areas as Labrador and the polar regions must be made productive in some way.

Our children will search far and wide for substitute raw materials for industry, especially in our key resources—minerals and fuels.

They will develop marginal resources like the oil-shale seams of the Rocky Mountains. Atomic energy for peaceful purposes will follow. Perhaps energy can be taken directly from the sun to turn the wheels of industry and run the electric fan, the TV set, and the refrigerator in your home.

These things may sound fanciful today, but they will be absolute necessities tomorrow. Our production must keep pace with our expanding population lest our nation stagnate and die.

In our educational institutions, we have the means for transmitting and enlarging the body of knowledge needed to create and direct the technology of the future. Let us strengthen and preserve them.

Above all, let us not dispense education in packages, neatly wrapped to prevent contact with anything else. Let us strive to produce technologists with an awareness of the rich heritage of other fields of study, and arts students with an appreciation of the economic facts of life about this world in which we live.

By so doing, we will enrich our nation with capable people and with such resources we most assuredly will go on to attainment of ever great heights.

* * *

Current Affairs

George W. Heise Receives Acheson Award

George W. Heise was awarded the Edward Goodrich Acheson Medal and Prize at a dinner held in his honor on Tuesday, October 5, 1954, during the 106th meeting of the Society at the Statler Hotel in Boston.

The Acheson Award is made for conspicuous "contribution to the advancement of any of the objects, purposes or activities" of the Society. Through the very breadth of the qualifications thus laid down by its founder, the senior medal of The Electrochemical Society has done high honor to any of its recipients.

GEORGE W. HEISE

George W. Heise was born on the shores of Lake Michigan in Milwaukee, Wisconsin, in 1888. There, he, a brother, and a sister grew up in a normal midwestern fashion, attending the public schools of Milwaukee. Exposing himself to the scientific training available there, he successfully completed his secondary schooling and entered a second—and very important, in view of later activities—phase of his career.

In the fall of 1905, Mr. Heise entered the University of Wisconsin and received the B.S. degree in 1909, the first year in which that degree was awarded for the four-year work in chemistry. It is easy to see how the seeds of enthusiasm for electrochemistry were planted during this period. Wisconsin in those days felt the influence of such forceful teachers as Louis Kahlenberg, known for his very positive, although perhaps not always successful, challenge of accepted theories of electrochemistry. There, too, was O. P. Watts, known for his contributions in corrosion and plating. It was at Wisconsin, also, that C. F. Burgess had organized a Department of Applied Electrochemistry and taught what was probably the first course in that subject in any American school. Of these associations Mr. Heise once said: "Fortunate indeed were those of us, not of the engineering school, who made the pilgrimage to the old Chemical Engineering Building to work in the applied electrochemistry laboratory with Dr. O. P. Watts and to attend the lectures of Professor Burgess—where we discoursed learnedly on overvoltage, theories of corrosion, cathodic depolarization in primary batteries, and the fundamentals of organizing and financing an electrochemical enterprise."

Thus a broad interest in electrochemistry had been established when, in 1909, Mr. Heise left Wisconsin, apparently to continue an academic career, first going to Grinell College for a year as instructor in chemistry, then to DePaul of Chicago for a second year during which he headed the newly organized Department of Physics, and was also responsible for the chemistry course for part of the time. While at DePaul he resumed graduate work in absentia in anticipation of his return to Wisconsin the following year. It was during this period of temporary defection from Wisconsin that Mr. Heise spent a summer at the University of Chicago under R. A. Millikan. While there he translated into German for publication in *Physikalische Zeitschrift* Millikan's epic work on the charge of atmospheric ions, which later became the basis for the award of the Nobel Prize.

Returning to Wisconsin in 1911 for graduate study, Mr. Heise worked under Kahlenberg and served as assistant in the Department of Chemistry. He received the M.S. degree in 1912 and spent the next year as fellow in chemistry, continuing work in physical chemistry under J. Howard Mathews, with research with Watts in electrodeposition on the side.

Up to this point the Medalist's activities showed every sign of beginning a promising academic career. That it did not continue was a loss to the teaching profession, for in many respects he is a natural born teacher and his basic viewpoint and philosophy have always been those of a teacher. However, Mr. Heise left the academic world in 1913 on one of his several excursions into the field of public service.

He joined the Philippine Bureau of Science at Manila as physical chemist. In the course of four years he became Chief of the Section on Weights and Measures, Water Supply and Physical Chemistry, and part of the time served as Acting Chief of the Division of Inorganic Chemistry. Mr. Heise took over the chemical laboratory and field survey work on water supply as part of a general program which was carried out in cooperation with the Bureaus of Health and of Public Works and which had a profound effect on the life expectancy and public health of the Philippines. In addition, he worked on corrosion, photosynthesis, electroanalysis, and radioactivity of ground waters and sea water. Versatility of the work is evidenced by the appearance of a series of over 30 papers in the *Philippine Journal of Science* and in the *Journal of Physical Chemistry*.

Perhaps one of the very early urges to do something about the dry cell may have arisen at this time. The work on radioactivity of waters necessitated riding out on native ponies to reach remote locations, and all equipment had to be carried by porters, 40 lb to the man. Geiger counters hadn't been invented in Heise's day in the Philippines, and the method of measuring radioactivity was to observe the discharge of an electroscope. A large wet storage battery of several hundred cells, available in the laboratory for charging electroscopes, obviously could not be carried to location at 40 lb per man. The method of charging was, actually, to develop static by rubbing a piece of ebonite. Anyone, faced with the strenuous effort of rubbing a piece of ebonite with a mangy cat skin, perhaps in the midst of a tropical downpour, would have both incentive and ample opportunity to dream up the very small, high voltage B batteries of today.

Serious influences of the Philippine phase were the associations with others in the Bureau at the time. Among these were R. R. Williams, of vitamin B fame, Elmer D. Merrill, the botanist, and Marshall A. Barber, the biologist famed for his work on malaria. There also was W. E. Pratt, geologist who later became a vice-president of Standard of New Jersey, and in Heise's own group was A. S. Arguelles who ultimately served as Director of the Bureau of Science. Some of these professional ties formed in the Philippines have persisted up to the present.

Another permanent tie was formed by the Medalist during his service in the Philippines. In 1915 he married Margaret Armstrong, and their family was founded in the Islands. Their son, Dr. George A. Heise, is Assistant Professor of Psychology at Oberlin College. Their daughter, Dr. Margaret D., now Mrs. W. D. Stevens of New York, was Assistant Professor of Bacteriology at Ohio State.

While still in the Philippines, Mr. Heise became aware of the first rumblings of World War I, and offered his services in the Reserve Corps when this country threatened to become involved. Returning to the States soon after, he received his commission, then taught again for a few months at Wisconsin until called into active service. Thereafter, throughout this country's participation, he served in the Army; first as Captain in the Utilities Department of the Quartermaster's Corps, he was adjutant, later acting officer-in-charge, of utilities at Camp Grant, Illinois.

After about a year of service at Camp Grant, Mr. Heise was transferred, as Captain in the Chemical Warfare Service, to the chemical plant at Saltville, Virginia. There, at the time of his separation from the Army, he was in charge of research projects related to the fixation of nitrogen by the Bucher process.

Apart from the basic interest in electrochemistry, the deciding influence affecting his career after he came out of the Army may have been his acquaintance with the late Dr. R. C. Benner, well known as a member of this Society and as the Director of Research for the Carborundum Company. In earlier years Dr. Benner was associated with National Carbon Company, and it was he who gave Mr. Heise his first introduction to the industrial technology of the dry battery. This field has been the backbone, although far from the entire substance, of the Medalist's subsequent career. During 34 years with National Carbon he served as department head for much of the research activity on the dry cell. He was largely responsible for the development and commercialization of air-depolarized cells, and made frequent and successful excursions into other battery fields, electrochemical synthesis, brine cell and porous carbon electrodes, special depolarizers, electrolytic condensers, as well as catalysts and sorbents.

Reviews of the early development of the dry cell have been covered, among other places, in Mr. Heise's address as President of the Society in 1948[1] and in review articles of 1952.[2] Suffice it to say that by the end of World War I a thriving industry had been established and radio was "just around the corner." Concepts of fineness, particularly as developed by Burgess, had opened up new vistas of service capacity for the miniature dry cell, without dependence on the expensive and erratic forms of artificial manganese dioxide then available, and important structural changes had been made, or were in the offing. Nevertheless, service was not generally considered a saleable feature; fundamental study had lagged, and only a small portion of the potential cell capacity was being realized.

The work of the Medalist should be viewed against this background. One of his early contributions was the development of a method of milling together the constituents of the dry cell bobbin, that is, depolarizer and carbon, which freed the dry cell for all time from the relatively expensive grades of graphite previously used, and also paved the way for what may have been the first commercial utilization of acetylene black in this country.

Much of his effort has also gone into fundamental investigation of the chemistry of the manganese system. This work by Heise and his colleagues, never completely interrupted at any time, has led, on the one hand, to more complete understanding of the reactions occurring in the dry cell, of their relation to depolarizing efficiency, of the distinct and characteristic functions of the electrolyte components such as zinc chloride and ammonium chloride, and of the crystallinity and other basic properties which are important in highly efficient manganese depolarizers. It also led, about 20 years ago, to an improved process for the electrolytic

[1] *Trans. Electrochem. Soc.*, **93**, 2*P* (1948).
[2] *This Journal*, **99**, 179*C*, 191*C* (1952).

production of manganese dioxide, which has had a major impact on the industry. This probably was the first such process successfully put into commercial production. Today, if any one factor can be considered pre-eminently responsible for the tiny and highly efficient dry cells in hearing aids, portable radios, and the like, it is probably the combination of electrolytically prepared manganese dioxide and acetylene black which made these possible.

Separators in the dry cell also received attention. Early work led to the introduction of kraft-type paper, now standard in some types of cells. More recently, with the advent of numerous resinous materials, Heise and his coworkers have developed thin resinous films which, unlike the older cereal paste and paper separators, combine extreme stability toward the chemical attack of manganese dioxide with almost ideal diffusion characteristics and high mechanical strength. These also are becoming standard in some types of cells. All in all, dry cell efficiency has increased more than threefold during the Medalist's career, much of it due to the work of his group.

Mr. Heise's activities covered battery systems other than those using manganese, foremost among these the Lalande and the alkaline air-depolarized cells. The fourfold increase in capacity of these alkaline batteries since 1920 is almost entirely due to this same group of workers. In the air-depolarized cell, zinc is oxidized by atmospheric oxygen at a carbon electrode. Long desired as a substitute for cells containing solid depolarizer, such as the copper oxide of the Lalande cell, several forms had appeared from about 1890 on. However, Mr. Heise was largely responsible for much of the research that transformed these earlier versions into the present commercial cell, outstanding for its constant voltage, and perhaps representing the most efficient of the commonly used galvanic systems. More recently the air-depolarized cell has been dried up, like the manganese cell, and reduced in size for use in hearing aids and the like.

Other gaseous depolarizers were not overlooked. The substitution of pure oxygen for air as depolarizer has permitted the development of an electrode capable of operation at more than 300 amp/ft^2. Similarly, hydrogen, chlorine, sulfur dioxide, carbon monoxide, hydrazine, and other gases were considered as depolarizers, both for use in batteries and for electrosynthesis. The work permitted construction of cells which were unique in that gases constituted the active elements at both electrodes, for example, hydrogen-oxygen, hydrogen-chlorine, sulfur dioxide-chlorine, carbon monoxide-oxygen. One important outgrowth of these studies was a chlorine depolarized battery which attracted considerable attention during World War II for heavy duty service, and which today remains among the most attractive of electrochemical systems when a high yield of energy from a minimum weight and volume is required.

The Medalist has been active in other electrochemical fields also. The development of a process for making electrolytic manganese dioxide, now recognized over other synthetic forms as the most desirable battery depolarizer has already been noted. The success of this program depended in large part on obtaining an improved graphite anode sufficiently resistant to anodic attack in acid manganese sulfate electrolyte. A suitable anode came from researches under Mr. Heise's supervision in the field of brine electrolysis and is now available to all makers of electrolytic oxide.

The work on brine electrolysis covered not only the graphite anode, but also process factors. Mr. Heise's group made substantial contributions to the better understanding of such factors as solution composition, current density, temperature, etc. Their results have led to improved anode performance.

Mr. Heise has always demonstrated outstanding talent, not only in achieving practical objectives, but also in recognizing the basic advantages and theoretical possibilities of new technical tools. An example of this talent was his ability to foresee that carbon of controlled porosity, manufactured primarily for gas diffusion and filter applications, had attractive possibilities as electrode material. On the practical side, it permitted continuous operation; on the theoretical side, it offered, in a sense, a stationary substitute for rapidly rotating electrodes or other mechanical devices, thereby partially removing limitations imposed by diffusion on all electrochemical processes. Based on these considerations, a number of potentially useful applications of porous electrodes were carried out, several of which have been described in the literature of this Society. Among these should be mentioned the electrowinning of copper, in which the use of the porous electrode can, under some conditions, reduce power requirements by more than half. Similarly, iron can be recovered from its ores or from waste pickle liquor. In the electro-organic field, the work of Heise's group showed porous electrodes could in large measure overcome the difficulties inherent in handling insoluble depolarizers or in recovering unstable products. Oxidation and reduction of inorganic chemicals, production of hydrogen peroxide from the oxygen of air, and conversion of sulfur dioxide to sulfuric acid were also among the researches on the porous electrode.

A measure of the Medalist's career can, perhaps, be obtained from a count of 45–50 publications, many of the papers having appeared in the TRANSACTIONS and JOURNAL of this Society, in addition to about 85 patents.

In describing these technical contributions, chronology has been of minor importance. To pick up the chronological thread, return to the years of World War II when Mr. Heise again rendered public service. He served as head of a group on a contract project with the National Defense Research Council and Chemical Warfare Service. The group was charged with the responsibility of producing from a domestic source a sorbent carbon suitable for the small, light-weight canisters then in use. This group made substantial contributions to the understanding of the relation between the structure of sorbent, or "activated," carbon and the high rates of sorption required for the thin layers of the modern canisters used by the military. The project was successfully brought to the level of a plant process for production of a good carbon without dependence on imported raw materials.

Closely related to this work on gas mask carbon was the development of so-called "catalytic" carbon, which has been described in part in the JOURNAL. In this project, Mr. Heise and his colleagues defined the acid counterpart of the alkaline system on which the air-depolarized cell is based, and showed that sorbent-type carbons can be modified so that they will sorb oxygen from the air in the form of an active carbon complex which can be used for chemical oxidations. In contact with such "catalytic" carbons, substances otherwise unaffected, such as sulfur dioxide, can be oxidized by atmospheric oxygen.

A year ago last July Mr. Heise reached the age conventionally referred to as "retirement" age. In this particular case, it was more a matter of "time for a change." He has continued his activities in batteries and allied fields. In addition to private consulting, which keeps him on the go, he serves the Committee on Undersea Warfare of the National Research Council as Chairman of the Panel on Primary Batteries.

No tribute to the Medalist would be complete without mention of his activities in professional societies. Long a member of The Electrochemical Society and active on many of its committees, he served as Vice-President in 1935–1936 and again in 1946. As President in 1947–1948 he carried the Society through a difficult transition period. At the section level, he was one of the founders and later Chairman of the Cleveland Section and has been a frequent speaker on electrochemical subjects before various Local Sections. He is a Fellow of the American Association for the Advancement of Science, and a member of the Faraday Society, the Society of Chemical Industry, the American Chemical Society, and Alpha Chi Sigma. He is a Registered Engineer in the State of Ohio, and his professional status is further attested to by authorship, now continued through several editions, of the primary battery section of the Encyclopedia Britannica. Among honorary scientific societies, he belongs to Sigma Xi and Phi Lambda Upsilon.

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1955 BOUND VOLUMES

Members and subscribers who wish to receive bound copies of Vol. 102 (for 1955) can receive the volume for the low, prepublication price of $6.00 if their orders are received at Society Headquarters, 216 West 102 Street, New York 25, N. Y., by *December 1*. After that date members will be charged $12.00 and nonmembers, including subscribers, $18.00.

NEWS ITEMS

Graduate Science Fellowships Offered by National Science Foundation

About 800 students with special abilities in science will be selected for a year of graduate scientific study during the academic year 1955–1956 in the National Science Foundation's Fourth Annual Graduate Fellowship Program. The closing dates for receipt of applications are December 20, 1954, for postdoctoral applicants, and January 3, 1955, for graduate students working toward advanced degrees in science. The selections will be announced on March 15, 1955.

National Science Foundation fellowships are awarded to United States citizens who will begin or continue their studies at the graduate level in the life and physical sciences (including interdisciplinary fields) during the 1955–1956 academic year.

Selections will be made solely on the basis of ability. The majority of the fellowships will go to graduate students seeking master's or doctor's degrees in science, although about 100 awards will be made to postdoctoral applicants. Science students who are now college seniors are encouraged to apply for the awards.

The rating system for selection of predoctoral Fellows will be based on: (*a*) scores on tests of scientific aptitude and achievement, (*b*) academic records, (*c*) written evaluations of each individual from his faculty advisors and other qualified observers. Postdoctoral applicants will not be required to take the examinations. Applicants will be rated by special Fellowship Panels, established by the National Academy of Sciences. Final selection will be made by the National Science Foundation.

Stipends for National Science Foundation graduate fellowships will vary with the academic status of the Fellows, from $1400 to $3400 per year. Dependency allowances will be made to all married Fellows. Tuition and laboratory fees and limited travel allowances will also be provided.

National Science Foundation Fellows may attend any accredited nonprofit institution of higher education in the United States or similar institutions abroad.

Applications for the 1955–1956 National Science Foundation Fellowship Program may be obtained from the Fellowship Office, National Research Council, Washington 25, D. C.

Mercast Forms New British Firm

Admiral Alan G. Kirk, Chairman of the Board of the Mercast Corporation, New York City, has announced that this company and Guest, Keen and Nettlefolds Limited, London, have jointly formed a British company, Mercast (Great Britain) Limited, to license the use of the Mercast process to firms in the United Kingdom and the British Commonwealth (excluding Canada).

The process, already gaining wide application in the United States, utilizes frozen mercury to form the expendable patterns for producing parts by the investment casting process. Since its development several years ago, it has enabled the precision casting of larger and more complex parts than were theretofore possible. Important uses for the process include components for the aviation industry and for atomic energy work. In addition, such parts as turbine blades, wave guides, pneumatic piston components, locking and hatch devices, generator and motor brackets, impellers, glass mold dies, and many other products have been successfully produced by the process.

American Mercast licensees include Alloy Precision Castings Company, Kolcast Industries, Inc., and Thompson Products, Inc., all of Cleveland.

American Directors of the new British firm include, in addition to Admiral Kirk, S. J. Sindeband, President of Mercast. The Chairman of the new company and other Directors represent British interests.

Bell Labs. Develops New Transistor

The time when home television sets will use tiny transistors about the size of pencil erasers instead of a large array of vacuum tubes came closer to realization with the recent announcement by Bell Telephone Laboratories of a transistor which will operate at 440 million cycles, higher in frequency than any transistor yet known.

Bell Laboratories, where the original transistor was invented, unveiled its latest member of the family of the "mighty mites" with a talk by Dr. J. M. Early before the Western Electronics Show and Convention at Los Angeles, Calif. Dr. Early invented the new transistor and was assisted in its development by W. C. Hittinger and Dr. J. W. Peterson.

Bell scientists forsee its use in portable radio sets, the transcontinental radio relay system, and submarine telephone and television cable repeaters. Used in military equipment, the device could be of tremendous importance to national defense.

The ultra-high-frequency device, called an "intrinsic Barrier" transistor, can increase an electrical signal a thousandfold. In addition to its ability to amplify signals, it may be used as a generator of electrical oscillations. The new device, like other junction transistors, can operate at extremely low power. But, unlike earlier transistors, it can also operate at relatively high power. Although the new transistor is still in the experimental stage, frequencies as high as 440 million cycles per second have been generated to date.

New Fluorine Cell to Aid Uranium Program

A boost for fluorine output, available in connection with the uranium 235 separation program, has been made possible through the development of a fluorine cell of advanced design by engineers of Union Carbide, operator of the uranium separation plants at Oak Ridge, Tenn., and Paducah, Ky., for the Atomic Energy Commission. This development was described recently at the Symposium on Fluorine conducted as a part of the American Chemical Society's national meeting at the Hotel Statler in New York. The description of the new fluorine cell was given by G. H. Montillon, a Carbide engineer. Coauthors of the paper were J. Dykstra, S. Katz, C. B. Clifford, and E. W. Lowell.

Known as a "medium-temperature electrolytic fluorine cell," it has considerably advanced in detailed design and maintenance techniques the method of obtaining fluorine, essential in producing the atomic fuel, uranium 235. It produces fluorine at lower cost, in less operating time, and at a much higher rate. It has doubled the life of previously available cells.

Since the new cell holds the promise of being adaptable for use in industrial processes generally, Carbide engineers have projected the idea into a typical plant to produce two tons of fluorine daily. Their description is based on the operation of a 36-cell unit. Description in full detail of the new cell design and of the operation of the unit is in line with the Nation's program of bringing developments in the atomic energy field to the attention of industry.

17-Year Exide Batteries

Storage battery users recently caught a fleeting glimpse of the industry's massive research effort when The Electric Storage Battery Company briefly lifted a veil of secrecy and revealed the existence of batteries lasting more than seventeen years. Previously seven years had been the best life normally attainable in the same service.

The company presented these battery performance records to the U. S. Patent Office several months ago in support of its sweeping claims for patent protection on new and improved battery grid alloys. Neither the firm nor the patent office made any announcement of the seventeen-year batteries. Only when the patents were awarded and published recently did the actual case histories become available to the industry for study.

The recently granted patents describe the alloying of lead with varying and precisely controlled quantities of antimony, arsenic, and silver, and use of these alloys in the grid structure of battery plates.

According to the patent, the seventeen-year case histories describe batteries maintained on "float," as in hundreds of industrial applications, including emergency lighting, switchgear control, fire alarm systems, telephone stand-by, railway signal control, and other stationary power applications requiring stand-by current. The company feels the new developments will have a significant effect on the service life of Exide storage batteries in all other industrial applications.

DIVISION NEWS

Luminescence Symposium, May 1955

The annual Luminescence Symposium of the Electronics Division of The Electrochemical Society will be held during the week of May 2, 1955, at the 107th meeting of the Society in Cincinnati, Ohio.

Detailed plans for the Symposium have not been set and, in fact, cannot be until titles and abstracts of papers have been received by H. Bandes, Vice-Chairman (Luminescence Group), Electronics Division, Sylvania Electric Products Inc., Bayside, N. Y.

A 75-word abstract, to be printed in the general program for the meeting, will be required by *January 15, 1955*. In addition, an "expanded abstract" of about 1000 words, along with curves, data, etc., will be due not later than *February 1, 1955*. This latter abstract will be "printed, not published" in the booklet of "Enlarged Abstracts of Papers Presented by the Electronics Division" which will be available both from the Secretary of the Division, and at the meeting, at cost.

The work of your Symposium Chairman will be greatly facilitated by early (preferably by November 15) notification of your intention to present a paper and by early receipt both of short and expanded abstracts.

Present plans indicate that there will be at least a two-day Symposium with one half day reserved for a Round-Table discussion and the remaining day and a half to be spent in separate, but not concurrent, sessions devoted to: (*a*) basic principles and phenomena, and (*b*) specific phosphor chemistry, structure, and behavior.

Dr. Ferd E. Williams, Research Laboratories, General Electric Company, will deliver the keynote talk and will act as Chairman of the basic principles session(s).

Following past practice, 20 to 30 minutes (including discussion) will be allotted each paper.

Following the plans of the Semiconductor Symposium of the Spring 1955 meeting, an attempt will be made to provide for 10-minute "late news" presentations. A deadline date of April 8, 1955, will allow for publicizing these "late news" items at least by mail to the members of the Division.

The Phosphor Screen Application Group, which was incorporated into the Luminescence Group in May, is organizing its own Symposium under the chairmanship of Dr. C. Dichter, General Electric Company, Syracuse, N. Y. The scope of the Group has been enhanced by deletion of "Screen" from its name.

H. Bandes, *Vice-Chairman*
(Luminescence Group)

Notice to Members

By now you have received your official voting ballot from Society Headquarters. If you have not already done so, please return the ballot by *December 15* so that your vote may be included in the final election count.

Semiconductor Symposium Planned for Cincinnati

The Semiconductor Group of the Electronics Division is making plans, to hold the third annual Semiconductor Symposium during the Cincinnati Meeting, May 1 to 5, 1955.

At present, plans are to divide the sessions as follows: two half-day sessions on semiconducting materials—elemental, alloys, and compounds; one half-day session on surface controlled phenomena; and one half-day session on chemical process technology.

In order to have a balanced agenda, it will be desirable to have a review paper of the status of each field, half-hour presentations of new information which can be scheduled by midwinter 1954, and a number of ten-minute presentations of the "late news" type.

Anyone wishing to present a paper at this symposium should contact F. J. Biondi, Bell Telephone Laboratories, Murray Hill, N. J., preferably *by November 15*, but not later than December 1, signifying interest in participating and title of proposed papers. This information is needed to plan the symposium.

No later than January 14, 1955, submit a 75-word abstract for inclusion in the program booklet. *No later than February 1, 1955*, submit a second "extended abstract" of about 1000 words, including brief pertinent data, curves, and illustrations. This extended abstract is "printed, but not published" in a booklet "Enlarged Abstracts of Papers Presented by the Electronics Division" and will be sold at the Cincinnati Meeting.

Symposium Planned by Metallurgy Section of the E & M Division

The Electrothermics and Metallurgy Division is scheduling a Symposium on "Electrochemical Techniques in Metallurgical Research" for the Spring Meeting of The Electrochemical Society to be held in Cincinnati, Ohio, May 1–5, 1955.

The scope of the Symposium will include: Metallography, Thermodynamics, Electroanalysis, Preparation of High Purity Metals, Atom Movements, and Electromachining.

Contributions for this Symposium are invited from all interested persons. It is desired that papers be contributions of original research and not merely reviews of a portion of the subject field.

Abstracts (not to exceed 75 words in length) and correspondence should be submitted *not later than January 3, 1955*, to the Chairman of this Symposium, Dr. J. H. Westbrook, General Electric Research Laboratory, The Knolls, Schenectady, N. Y.

NEW MEMBERS

In September 1954 the following were elected to membership in The Electrochemical Society:

Active Members

MANUEL BEN, General Motors Corp., mail add: 13430 Rosemary Blvd., Oak Park 37, Mich. (Corrosion, Electrodeposition)

FRANK J. BIONDI, Bell Telephone Labs., Murray Hill, N. J. (Electronics)

EMANUEL L. BRANCATO, Naval Research Lab., mail add: 5707 47th Ave., Riverdale, Md. (Electric Insulation, Electrodeposition, Electronics, Theoretical Electrochemistry)

PHILIP CRISPINO, Foster D. Snell Inc., mail add: 1341-43rd St., Brooklyn 19, N. Y. (Battery, Theoretical Electrochemistry)

JAMES LESLIE CURTIS, Marathon Paper Mills of Canada Ltd., mail add: 9 Drake St., Marathon, Ontario, Canada (Industrial Electrolytic)

JOSEPH DE MILIA, U. S. Naval Gun Factory, mail add: 4812 41st St. N. W., Washington 16, D. C. (Electronics)

JULIAN J. DRAVIS, Canadian Westinghouse Co. Ltd., Sanford Ave. N., Hamilton, Ontario, Canada (Industrial Electrolytic)

LINDSAY DUNHAM, Ets. Daniel Doyen S. A., 31–32 Blvd. du Midi, Brussels, Belgium (Battery)

OTTO H. FENNER, Monsanto Chemical Co., 1800 South Second St., St. Louis 4, Mo. (Corrosion)

PHYLLIS E. FOWLE, Aluminum Co. of America, mail add: 304½ Charles Ave., New Kensington, Pa. (Theoretical Electrochemistry)

GUNNAR L. GABRIELSON, AB Tudor, Nol, mail add: Friggagatan 25 A, Göteborg C, Sweden (Battery, Electrodeposition, Theoretical Electrochemistry)

WILLIAM C. HANNAH, Ball Bros. Co., mail add: 2 Elizabeth Ave., Muncie, Ind. (Battery)

NAAMAN H. KEYSER, Battelle Memorial Institute, 505 King Ave., Columbus 1, Ohio (Electrothermics and Metallurgy)

ERICH LAUE, MacDermid Inc., mail add: Plungis Rd., Watertown, Conn. (Corrosion, Electrodeposition, Theoretical Electrochemistry)

NATHANIEL H. LIEB, Star Dental Mfg. Co., Inc., mail add: 5216 Lebanon Ave., Philadelphia 31, Pa.

FREDERICK R. MEYER, Southern New England Telephone Co., Administration Bldg., 227 Church St., New Haven, Conn. (Corrosion)

ARTHUR R. NASRALLAH, Goodyear Aircraft Corp., mail add: 2233-25th St. S. W., Akron 14, Ohio (Corrosion)

BIAGLIO PESCE, University of Rome, mail add: Laboratorio di Chimica Fisica del l'Università, Rome, Italy (Theoretical Electrochemistry)

ARTHUR G. PIERDON, Art Metal Finishing Co., mail add: 5331 42nd St. N. W., Washington 15, D. C. (Electrodeposition)

EUGENE C. RAGATZ, Allen-Bradley Co., 136 W. Greenfield Ave., Milwaukee 4, Wis. (Electronics)

ÄKE HENRY L. ROSENDAHL, AB Tudor, Nol, Sweden (Battery)

ALAN B. ROTHMAN, Westinghouse Electric Corp., mail add: 5624 5th Ave., Apt. C-8, Pittsburgh 32, Pa. (Theoretical Electrochemistry)

PAUL RUETSCHI, Louisiana State University, College of Chemistry, Baton Rouge, La. (Battery, Theoretical Electrochemistry)

SIDNEY M. SELIS, Diamond Ordnance Fuze Labs., mail add: 12408 Dalewood Dr., Silver Spring, Md. (Theoretical Electrochemistry)

THOMAS J. VINCENT, General Electric Co., mail add: 1099 Ivanhoe Rd., Cleveland 10, Ohio (Electronics)

OTTO J. VONDRAK, Kaiser Aluminum & Chemical Corp., mail add: 4618 Gaines St., New Orleans, 22, La. (Industrial Electrolytic)

WILLIAM G. WALLACE, Aluminum Co. of Canada, mail add: 196 Radin Rd., Arvida, Quebec, Canada (Industrial Electrolytic)

RAYMOND WARD, General Electric Co., Industrial Heating Dept., Rm. 105, Bldg. 96, Schenectady, N. Y. (Electrothermics and Metallurgy)

Associate Members

GEORGE B. COBEL, Dow Chemical Co., Bldg. 228, Midland, Mich. (Electro-

thermics and Metallurgy, Industrial Electrolytic)

HERBERT B. FISHMAN, General Dynamics Corp., mail add: 258 Lower Blvd., New London, Conn. (Corrosion, Electrodeposition)

PHILIP T. GREEN, Panama Canal Co., mail add: Box 213, Balboa, C. Z. (Electric Insulation)

RANKO SAMANTO ROY, Khallikote College, Berhamper, Ganjam District, Orissa, India (Theoretical Electrochemistry)

Student Associate Member

JOHN D. HORA, Inland Steel Co., mail add: 7034 Colorado Ave., Hammond, Ind. (Electrodeposition)

Reinstatements—Active

ANTONIO SCORTECCI, Istituto Siderurgico Finsider, Corso F. M. Perrone 24, Genova, Cornigliano, Italy (Electrothermics and Metallurgy)

ROBERT D. WILLIAMS, Fulbright Labs., Inc., mail add: P. O. Box 1284, Charlotte, N. C. (Corrosion, Theoretical Electrochemistry)

Reinstatement—Associate

R. R. WITHERSPOON, Army Chemical Center, mail add: Pvt.—U. S. 55435664, 9710TSO, ACml C Det. 2, Army Chemical Center, Md. (Battery)

Transfers to Active

THEODORE A. HIRT, Pittsburgh Steel Co., mail add: 654 Elm Rd. N. E., Warren, Ohio (Electrodeposition)

WILLIAM W. GULLETT, Chicago-Delaware Co., mail add: 6903 Baltimore Ave., College Park, Md. (Battery)

GEORGE L. SCHNABLE, Philco Corp., mail add: 36 S. Wyomissing Ave., Shillington, Pa. (Electronics, Theoretical Electrochemistry)

Transfers to Associate

ATTILIO L. BISIO, American Smelting & Refining Co., mail add: 25-20 21st St., Astoria 2, N. Y. (Corrosion, Electrodeposition)

JAMES CHRISTIAN LAMB, III, Mass. Institute of Technology, mail add: 15 Appletree Lane, Lexington, Mass. (Corrosion)

YEN-NGEN WANG, Crane Co., mail add: 3724 Washtenan Ave., Chicago 32, Ill. (Corrosion, Electrodeposition)

Resignations

J. E. HAWKINS, Dept. of Chemistry, University of Florida, Gainesville, Fla.

HAROLD LUNDIN, 6515 Blvd. East, Apt. 7D, West New York, N. Y.

LYNNE G. WIEDENMANN, 503 17th Ave., East Moline, Ill.

JOHN K. WERNER, Bldg. 5, Apt. B5, 100 Franklin St., Morristown, N. J.

RALPH L. HORST, JR., 4842 Ellsworth Ave., Pittsburgh, Pa.

ECS Membership Statistics

The following two tables give breakdown of membership as of Oct. 1, 1954. The Secretary's Office feels that a regular accounting of membership will be very stimulating to membership committee activities. In Table I it should be noted that the totals appearing in the right-hand column are *not* the sums of the figures in that line since members belong to more than one Division. But the totals listed are the total membership in each Section, with the exception that Sustaining Memberships are not broken down by Sections or Divisions. Since Sustaining Members are not broken down by Sections or Divisions, the total listed in Table I will be less than the total in Table II, the difference being the total number of Sustaining Memberships.

TABLE I. *ECS Membership by Sections and Divisions*

Section	Division												
	Battery	Corrosion	Electric Insulation	Electro-deposition	Electronics	Electro-Organic	Electrotherm-ics & Met.	Industrial Electrolytics	Theoretical	No Division	Totals As of 10/1/54	Total As of 7/1/54	Net Change
Chicago	12	32	3	48	11	8	8	8	17	10	100	104	−4
Cleveland	37	34	5	48	29	7	19	25	39	11	152	153	−1
Detroit	6	18	6	33	5	7	4	3	19	11	67	65	+2
India	6	5	3	13	3	4	6	17	6	4	34	33	+1
Midland	6	13	0	6	1	2	5	13	6	3	36	35	+1
New York	59	102	18	129	70	30	46	55	79	57	403	404	−1
Niagara Falls	4	15	0	14	3	7	41	41	12	14	109	109	0
Pacific Northwest	5	10	0	7	3	2	5	12	9	4	31	31	0
Philadelphia	23	26	6	33	41	17	16	14	37	23	154	153	+1
Pittsburgh	3	25	4	17	7	5	19	13	21	10	69	69	0
San Francisco	7	10	1	15	7	3	6	14	10	4	42	39	+3
Washington-Baltimore	33	34	11	27	14	3	14	14	27	9	99	99	0
Ontario - Quebec	7	11	0	13	0	3	16	19	7	13	45	0	+45
U. S. Nonsection	66	159	27	170	93	56	95	104	149	80	632	622	+10
Canada Nonsection	0	2	0	0	0	3	1	0	0	0	5	52	−47
England	6	8	2	10	4	3	6	8	8	17	38	37	+1
Foreign Nonsection	19	29	4	40	14	17	21	39	42	47	145	143	+2
Total as of 10/1/54	299	533	90	623	305	177	328	399	487	317	2161		
Total as of 7/1/54	299	533	88	621	299	178	326	397	478	318		2148	
Net Change	0	0	+2	+2	+6	−1	+2	+2	+9	−1			

TABLE II. *ECS Membership by Grade*

	Total As of 7/1/54	Total As of 10/1/54	Net Change
Active	1895	1911	+16
Delinquent	90	83	−7
Life	14	14	0
Emeritus	34	35	+1
Associate	73	74	+1
Student	37	39	+2
Honorary	5	5	0
Sustaining	103	103	0
Total	2251	2264	+13

PERSONALS

WILLIAM J. KROLL of Corvallis, Oreg., has been awarded a Francis J. Clamer Medal by The Franklin Institute of the State of Pennsylvania. Dr. Kroll was out of the country at the time and the award was made in absentia, to be formally presented to him at a later date. The Institute honored Dr. Kroll "In consideration of his invention of a method adaptable to the large scale production of cold malleable commercially pure titanium and zirconium," as reads the citation to the award.

WILLIAM E. TRAGERT, formerly a student at Yale University, has joined the staff of the General Electric Research Laboratory, Schenectady, N. Y., as Research Associate.